Textbook of Dental and Maxillofacial Radiology

VISIT…

Textbook of Dental and Maxillofacial Radiology

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Foreword

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It gives me great pleasure to write a *foreword of "Textbook of Dental and Maxillofacial Radiology"*, authored by Dr. Freny R. Karjodkar, Associate Professor and Head of the Department of Oral Medicine and Radiology, Nair Hospital Dental College, Mumbai.

She is a dental educator and researcher, who has succeeded in producing an eminently readable, comprehensive work in the field of Dental and Maxillofacial Radiology.

The present book provides recent insights based upon knowledge of the latest research in the field of radiology. Dr. Karjodkar has directed her understanding of Radiology to the dental surgeon and dental student, and has selected topics in radiology in accordance with the syllabus of Dental Council of India and Universities all over India. All the topics receive highly critical attention with the most important areas clearly emphasized.

This book has not only covered the conventional chapters but newer advances in the field have been discussed and introduced in a comprehensive manner, at the same time it is a valuable source of information concerning often used but not fully understood radiographic techniques. It is hoped that this up to date monograph on modern dental radiography, together with future radiographic research will provide the bridge to a new era in the holistic treatment of the dental patient.

The author deserves hearty congratulations for her excellent contribution and I am sure that this book will not only facilitate all dental students but also the general practicing dental professional to understand and gain insight of the sophisticated modern radiographic techniques and their clinical applications.

Prof. S.G. Damle
Jt. Municipal Commissioner
Medical Education and Public Health
Municipal Corporation of Greater Mumbai.
Dean,
Nair Hospital Dental College, Mumbai

"Guru Gobind dau khade

Kake Iagu pai....

Balihari Guru apne

Gobind diyo batai..."

....Sant Kabir

This book is dedicated to

"ALL MY TEACHERS"

whose perseverance, understanding and encouragement has inspired and helped me to reach my goals.

Preface

This earth is His, to Him belong those vast and boundless skies;
Both seas within Him rest, and yet in that small pool He lies.

Atherva Veda
Book 4, Hymn 16

Unlike his medical colleagues, the dentist has the unusual opportunity, as well as the responsibility of being his own radiologist. Not only must he take his own radiograph, but he must also interpret them.

In actuality dental radiology is the "Cinderella" of dentistry, and despite the fact that it is well taught in most dental schools, it is on the whole poorly learned by the average practicing dentist. The quality of the dental radiographic technique is in general equally poor, that as a consequence, most dentists are unacquainted with the radiographic appearances of all but a few of the most common pathological processes that may occur in and about the teeth and jaws. As a rare consequence of this, serious or even grave outcome occurs for the patients.

The interpretive and technical aspects of dental radiology have necessarily suffered on several accounts. First, radiology has only very recently been recognized as a specialty within the dental profession. Compared to the other specialties it receives relatively little attention in the undergraduate curriculum. Second, every dentist will provide his own X-ray services and will have a depth of experience which is directly related to the characteristics and size of his own patient population. Third, most disease found in the jaws is chronic and benign, rarely leading to procedures that require histological examination. Confirmation of a radiographic diagnosis is, therefore, infrequent.

Expertise in dental radiology is, therefore, limited. A few individuals in large institutions have an opportunity to analyze thousands of patient examinations each year. Unfortunately, even within institutions, the ability to record, confirm, catalog and study the results of many patient examinations is severely restricted.

Dental Radiography has changed dramatically in the last decade, we are on the threshold of major alterations in practice patterns. There is a growing consciousness about the potential hazards of exposure to ionizing radiation, and there is increasing recognition of the limitations of the currently used technical procedures.

This book has been prepared to present a new, simple and easy to consult approach to the taking and interpretation of radiographs. It is an attempt to provide an insight into developing trends in dental radiology, from a technological and interpretive point of view. We have attempted herein to meet the needs of students and practitioners. We hope to give the dental student the basic knowledge necessary in this field and the help the general practitioner, who will find it necessary to modify their practice patterns in the future. Last but not the least this book will also help the general radiographer to over come what has become an irrational fear of "dental work".

I wish to express my gratitude to all the people involved in the writing of this book,

The staff of Nair Hospital Dental College, in particular our Dean Dr. S.G. Damle for his encouragement for doing any scientific projects, my colleagues, Dr. K. Sansare for his tangible, but always unspoken support for this project, Dr. S. Khanna for her support, suggestions and useful criticism. My postgraduate students, Dr. Antra Sinha, Dr. Vikrant Kasat, Dr. Ambika Gupta and Dr. Neeraj Sharma who helped me with the proof reading, captions, to update and supplement original photographs and line diagrams.

It has been a pleasure to work with Jaypee Brothers, and the co-operation of the editorial and production staff in Mumbai and Delhi is well appreciated.

My deepest gratitude to my mother and aunt for their unfailing emotional support during the writing.

This book has been written during the hours I would normally have spent with my husband Rashmiraj who is my unsparing critic, my sincere thanks for his tough comments and gentle support, and my children Mohnish and Raveena, I acknowledge their understanding and unselfish co-operation.

Freny R. Karjodkar

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Section One
Introduction

1

History of Radiology

PROLOGUE TO DISCOVERY

Nothing materializes as if by magic overnight. Even Roentgen's discovery depended upon the development and application of three converging thoughts; Electricity, Vacuum and Magnetism.

History began long back in 600 BC when a Phoecian voyager Thales of Miletus, was first to tread the darkness and obtain a "delicate substance, fair in color and beautiful in transparency" from the Baltic Shores. He named this substance as e- or amber and noted that it attracted light particles of matter when rubbed. His work was enlarged upon by Theophrastus (321 BC), Pliny and William Gilbert. Gilbert (1600) classified all things into electric or nonelectric and gave the term "electricity". Stephen Gray discovered that current would flow over a conductor for great distances. Abbe Nollet utilized iron chains to carry high potential current from his electric machine to evacuate glass vessels, he was using to study high tension discharges. Thus, he removed the source of high tension from vacuum and his "electric egg" became the direct descendent of the discharge tube. Charles DuFay (1730) discovered two types of electricity, i.e. 'vitreous' and 'resinous' which Franklin called 'positive' and 'negative' electricity.

Otto von Guericke (1648) invented the first air pump used in the formation of vacuum. He reasoned that earth, moon and other heavenly bodies must be moving in empty space, otherwise resistance of air would bring them to a standstill. This leds to his experiment on 'Magdeburgh Hemispheres' and demonstrated the properties of a vacuum. Evangelista Toricelli's mercury barometer (1643) produced the first permanent vacuum located in empty space above the mercury column. Sixty years later, Francis Haulisbec, the Elder designed and operated a small electricity producing friction machine within a vacuum.

DISCOVERY OF X-RAYS

Sir William Morgan (1785), while investigating the discharge of high tension currents in perfect vacuum, obtained a vacuum so high that there was no discharge. In one of his experiments, the glass cracked and Morgan observed a display of colors, beginning with yellow-green and followed by red, violet and blue. Unknown to him he was the first man to produce X-rays.

In 1821, Michael Faraday conducted his first experiment on electric discharges in partially evacuated glass vessels using a vacuum pump built in 1650 by Otto von Geuricke. He described that the 'voltaic arc' was accompanied by fluorescence of gas remaining within the vessel. He called the fluorescence as 'radiant matter,' and considered it as the fourth state of matter. In 1831, he described electro-magnetic induction which N. Tesla applied for the construction of high tension coils and Ruhmkorff in turn modified it as a convenient source of intermittent high voltage.

Julius Plucker (1859) was the first to observe Green Gas Fluorescence in partially evacuated discharge tubes. He also studied the influence of magnet on the cathode emissions.

Wilhelm Hittorf (1870) improved vacuum pumps. He observed that the fluorescent discharge increased in size as the tube was evacuated and identified the source of the phenomenon as cathode and termed it as 'cathode rays.' He found that these rays traveled in straight lines, produced heat and caused fluorescence on glass where it impinged, cast shadow of the object placed in its way and was deflected by a magnet. His work was subsequently verified by Eugen Goldstein (1879).

In 1880s, Sir William Crookes described additional changes that took place in the fluorescence. He considered 'radiant matter' to be the 'ultra gaseous state.' He found that the freshly opened photographic plates were strangely fogged and blackened. He referred to a 'molecular' and 'emissive' ray from his tube which could only be seen when a fluorescent screen was placed in the ray's path beyond the tube. He had unconsciously and unknowingly generated X-rays. He determined that the cathode rays have momentum

and energy and that they were a stream of charged particles, he subsequently redesigned the tube.

Heinrich Hertz denied that cathode rays were charged particles, but observed that they could penetrate matter. Philip Lenard showed that cathode rays would pass through a special aluminum window built into the wall of his discharge tube and retained enough energy outside the tube also, to cause fluorescent screen to glow. These rays caused air to glow in front of the window. This glow extended in all directions for about five centimeters in air and became known as 'Lenard's Ray.' Lenard might have been the discoverer of X-rays, had he used barium platinocyanide instead of a less sensitive fluorescent material, keton (pentadecyl paratolyketon) because he was not permitted access to Dr Hertz's supply of platinocyanide. Hence, because of the less sensitive keton, he could not observe the fluorescence at distances more than eight centimeters from the tube. He was able to demonstrate the effect of Lenard's Rays on photographic emulsion as well as the effect of causing a charged electroscope to discharge at a distance of thirty centimeters from his tube. Lenard proposed the 'Inverse Square Law.'

In 1895, Jead Perrin stated that cathode rays were negatively charged particles. In 1896, John Joseph Thomson resolved the debate between Crookes and Hertz, relative to the nature of cathode rays when he measured their velocity and the ratio between their charge and mass and thereby discovered the 'electron' (Fig. 1.1).

Humanity owes honor and gratitude for discovering the most striking and outstanding property of cathode rays to Professor Wilhelm Conrad Roentgen of Wurzberg, Bavaria (1895) (Fig. 1.2). Roentgen, while experimenting and searching for the invisible light rays turned on a low pressure Crooke's tube (Fig. 1.3), completely enclosed in heavy black paper and applied power to the electrodes with a Ruhmkorff

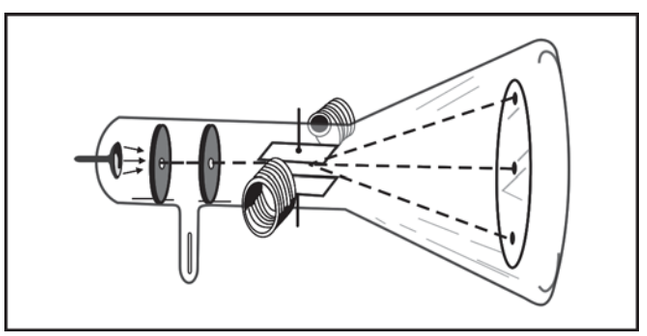


Fig. 1.1: Diagram of the cathode ray tube used by JJ Thomson when he discovered the electron

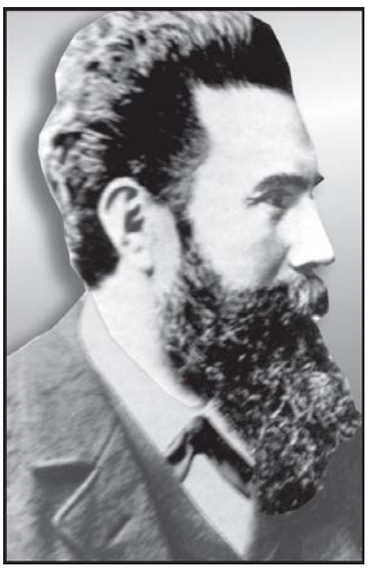


Fig. 1.2: Wilhem Conrad Roentgen (1845-1925) – The discoverer of X-rays

Induction Coil (Fig. 1.4). Immediately to his surprise, a fluorescent screen, covered with barium platino-cyanide standing on a table, some distance away, started to glow brightly. When he interposed objects between the tube and the screen, shadows were cast on the screen.

Tracing back the rays to their source, he revealed that the rays were produced whenever and wherever the cathode

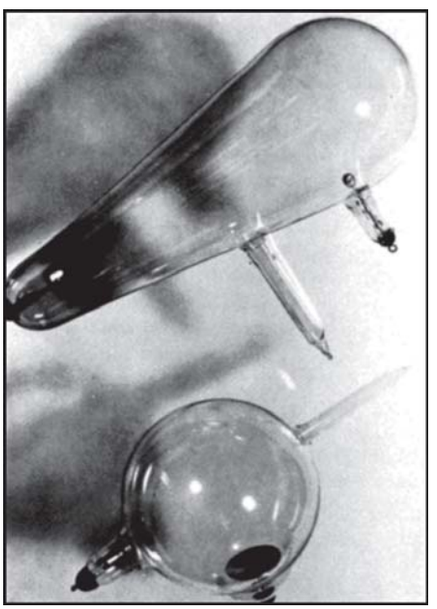


Fig. 1.3: Hittorff- Crooke's tubes, of the kind used by Roentgen to discover X-rays

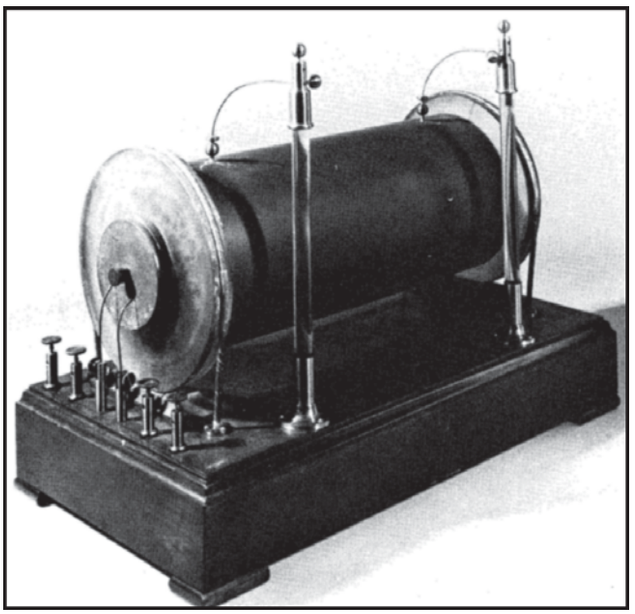


Fig. 1.4: Ruhmkorff Induction Coil used to power early tubes

Fig. 1.5: First radiograph, which was the hand of Roentgen's wife Bertha Roentgen. Note images of soft tissue, bones and two rings

rays encountered matter and that the rays could penetrate substances opaque to light, and the degree of penetration depended upon the density of the substance. These rays could not be reflected or refracted. They were unaffected by a magnetic or electric fields as was the case with cathode rays. He termed these rays "X-rays" after the mathematical symbol for the unknown—"X." Since 'X' was considered the American way to term the unknown, he ultimately, called them 'Roentgen Rays.'

While investigating Roentgen accidentally placed his hand between the tube and the fluorescent screen only to be surprised by seeing a faint but startling image of the bones within his hand on the screen; the property of fluorescence and penetration. He subsequently demonstrated that such images of the body could be recorded on photographic plates.

Roentgen proceeded to make the first radiograph of the human body; he placed his wife's hand on a photographic plate and exposed it to the 'unknown rays' for 15 minutes. When Roentgen developed the photographic plates, the outline of the bones in her hand could be seen (Fig. 1.5). He published three papers—

1. A new kind of Rays: A preliminary communication.
2. A new kind of Rays: continued.
3. Further observations on a new kind of Rays.

So complete and detailed were his studies and descriptions of the nature of X-rays that over the next fifteen years, only the fact that X-rays could be polarized and defracted were to be added to the existing information. Roentgen was awarded the first Nobel Prize in Physics (1901), a Honorary M.D. Degree from Maximilan University in Wurzberg, the Rhumford Gold Medal of the Royal Society (British), the Iron Cross from Hindenberg, etc. The first medical radiograph was of Mrs Roentgen's hand and the first industrial radiograph was of Roentgen's shot gun.

It is believed that the first dental radiographs were made by Professor Wilhelm Koening in Frankfurt and Dr Otto Walkhoff; (Fig. 1.6) a dentist in Brunschweig, Germany, with the help of a radiochemist Giesel (1896). Walkhoff used a 25-minute exposure which was too long and the equipment too costly.

In the same year, Frank Harison (England) made a dental radiograph using a 10-minute exposure. He also described his X-ray images as demonstrating the pulp chamber of the teeth. He was probably the first to report the occurrence of radiation hazard.

William J Morton, a physician was the first in US to announce that radiographs of teeth were possible. On April 24,1896, he gave a lecture on X-rays at a meeting of New York Odontological Society and showed dental radiographs made on a skull.

Dr C Edmund Kells (1880), (Figs 1.7 and 1.8) also known as the *father of dental radiology*, fitted his office with an electric equipment, all of his own design. With the help of Professor Brown Ayres, he acquired a Ruhmkorff coil and several Hittorf-Crookes tubes and took the first intraoral radiograph in US on a live person in 1896. He

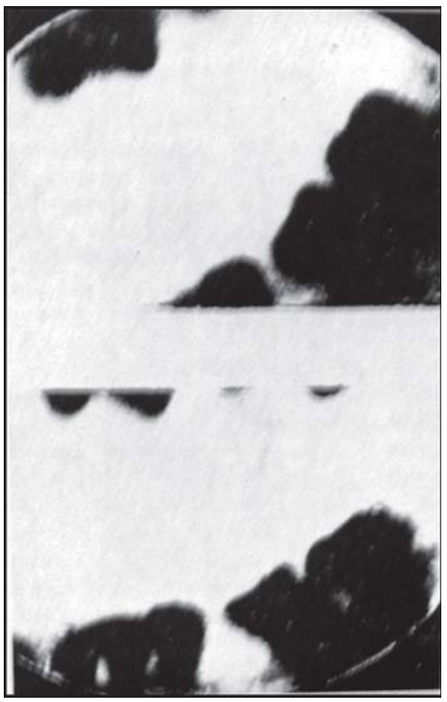


Fig. 1.6: First dental radiographs, made by Dr Otto Walkhoff

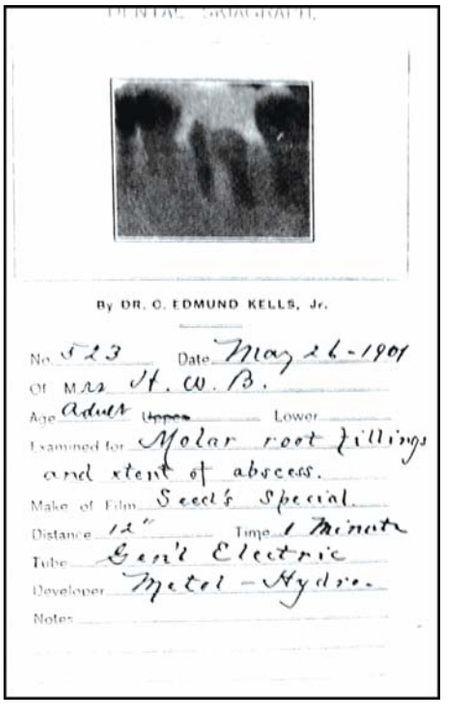


Fig. 1.8: Dental X-ray record made by Kell's in 1901

designed his own dental X-ray apparatus for holding the tube and technique for radiographing the teeth and jaws. In an article published in1899 (Dental Cosmos), he mentioned the importance of keeping the film and object at right angles to the source of X-rays, using a film holder.

"Roentgen Studies" appeared in America and Europe and advertisements announced businesses in "Roentgen Photography" with appointments being made for 'X-ray sittings.' These "radiological chemist" used four fundamental pieces of apparatus:

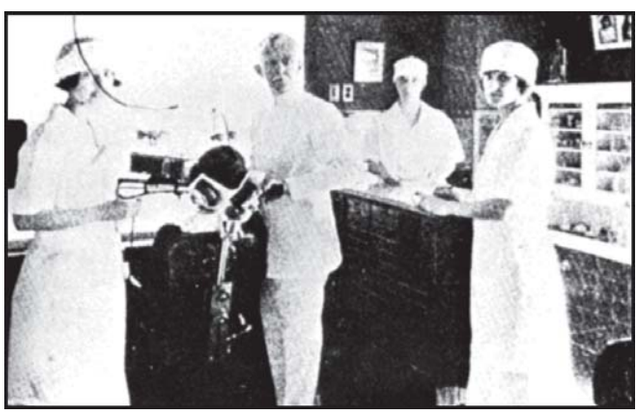


Fig. 1.7: C. Edmund Kells in his dental clinic

1. X-ray machine.
2. X-ray tube.
3. Adjustable tube stand.
4. The darkroom.

The X-ray machine consisted of three basic components—the induction coil, the interrupter, the rheostat. The induction coil or transformer provided a source of high potential current for the X-ray tube. The coil consisted of an inner or primary coil containing a few turns of coarse wire wrapped around a core of soft iron, this was known as the magnetic core. The outer or secondary coil was made up of many turns of insulated fine wire. The induced current in the secondary coil depended on the ratio between the number of turns in the primary coil and the number of turns in the secondary coil.

The induction coil was connected in series with the interrupter or rheotome. Rheotome rapidly interrupted the primary current going into the primary coil and thereby created rapidly succeeding magnetic impulses necessary to maintain a constant flow of current from the secondary coil to the X-ray tube.

There are two basic types of interrupters:

1. Mechanical
   i. Vibrating type.
   ii. Mercury type.

2. Electrolytic

Vibrating type consisted of a rapidly vibrating bar that could rapidly make and break the primary current (similar to the door bell). These were supposed to be less dependable than the mercury type.

Mercury type used an electric motion to dip a platinum tipped rod in and out of a container of mercury.

Electrolytic type, the most universally used, was designed by Wernelt in 1899 and it depended upon the formation of gas bubbles at the poles of an electrolytic bell, consisting of a jar containing sulphuric acid (dilute), a lead plate (cathode) and a platinum rod (anode), insulated except at its tip. Current passing to the platinum point created hydrogen bubbles which acted as source of insulation. As the bubbles increased in size, current flow decreased and finally stopped. (This produced "make current"). When the current flow ceased, the bubbles dispersed and the solution again contacted the electrode, re-establishing current flow. (This produced "break current").

Make current was induced in the secondary coil during the building of current inside the primary coil. It was of a low voltage and in the wrong direction (inverse current). It was not helpful in exciting the X-ray tube. The break current was produced when the interrupter opened the primary circuit with the release of gas bubbles. The primary current stopped, the magnetic field quickly collapsed, inducing a very high voltage within the secondary coil opposite to the flow of 'make current'. This high potential current was used to excite the X-ray tube.

Spark gap or valve tubes arranged in series with X-ray tube was used to regulate make current. These interrupters were capable of interrupting the primary current from 1000 to 4000 times per minute, depending upon the amount of point exposed. Spark gap served the function of cutting out the weaker "inverse" current without interfering with stronger current delivered to the terminals of X-ray tube. Inverse current having less potential than break current could not pass through the air resistance across the spark gap. The disadvantage of this was that during electrolysis, sulphuric acid became hot, causing interruptions to become irregular.

The Ruhmkorff coil was eventually replaced by the Jumbo coil designed by H Clyde Snook (1904) which in turn was rapidly replaced by Tesla or high frequency coil. Tesla coil was a double induction coil in which the secondary of one transformer acted as primary of the other. The stepped up current from the alternating current transformer went to a condenser and then into the primary of the Tesla or second coil, where it induced a current. The current from the final secondary was then passed to the X-ray tube. The Tesla coil produced a high voltage, low amperage alternating current to a specially constructed X-ray tube.

The X-ray tube used by Roentgen, Lenard, Crookes and other early pioneers were fixed or stationary vacuum type. Vacuum in these tubes could not be altered during the life of the tube which resulted in a considerable amount of variability in quality of X-ray beams produced. So, each tube had to be tested to determine its penetrating qualities before it could be used on patients. The tube testing procedures used were:

- By observing the color of fluorescence in the energized tube.
  i. Low vacuum—dark blue.
  ii. High vacuum—more uniform yellow or apple green color.
- By observing the amount of spark 'backed up' across the spark gap of the induction coil.
  i. Three to four inches spark—soft X-rays.
  ii. Seven to ten inch spark—high vacuum, high penetrating X-rays.

  An ideal spark for dental purposes was 4 to 7 inches in length with a "fat fuzzy caterpillar like" appearance.
- Thomas A. Edison met the accuracy requirement which the first two methods lacked, when he invented the fluoroscope. Edison used a fluorescent cardboard screen composed of calcium tungstate crystals surrounded by a card board tube to exclude light. But this was a lethal procedure, because the operator positioned his hand in front of the screen exposed with X-rays to see the quality, every time the radiograph was taken. Later the human hand was replaced by an osteoscope of Carl Beck (articulated skeleton's hand and forearm, held by the operator whose hand was enclosed in a protective shield).
- Later, the quality of X-ray beam was estimated by using its ability to penetrate varying densities on a device called "penetrometer." Benoist radiochromatometer was the first device. It consisted of a central disk of silver surrounded by a circular step wedge of aluminum of thickness varying from 1 to 12 mm. The silver maintained the same density, radiographically, regardless of the penetration of the X-ray beam. A film was taken of the penetrometer and the shadow of one of the aluminum section was compared in density to that of the silver disk. If the density was same it was considered to be no.5 Benoist. This instrument measured only the maximum penetrating power of the X-ray beam.
- Another device, called the Qualimeter, registered the resistance in the secondary circuit of the transformer.

i. High vacuum—high resistance—high penetrating X-rays.
ii. Low vacuum—low resistance—low penetrating X-rays.

The milliamperemeter was developed by Snook (1904) measured the current flowing through the tube.The penetrometer, qualimeter and the milliamperemeter were used simultaneously to give a reasonably reproducible estimates of tube quality, provided the tubes and the apparatus remained unchanged from one time of measurement to the next. This procedure was known as 'closing the tube.'

- The quality of emitted X-rays could be measured by means of the Holznecht radiometer by exposing barium platinocyanide plate with X-rays. When fresh it appeared bright green, when exposed to increasing quantities of radiation it assumed at first a yellowish brown, then a brown and finally a reddish brown color.

  The exposed tablet was compared with a standard color scale and the readings were given in 'H' units (Holzknecht). 1 H unit was one-third the quantity of radiation necessary to produce an erythematous reaction on skin of a middle aged man (appx. 100 r).

Gas Tubes

Early vacuum tubes depended upon the incomplete vacuum to provide the source of electrons at the cathode. As the tube was used, the gas molecules combined with or were trapped by vaporized residues from the anode and cathode which gradually increased the vacuum. When the vacuum became too high, no X-rays were produced and the tube was considered to be 'cranky.' This 'cranky' tube could be heated by an alcohol lamp to drive gas molecules from its walls which maintained continued production of X-rays.

Regulator Tubes

To increase the longevity of X-ray tube, self-regulating and regenerative tubes were developed in 1896 by Queen and Company, in which a degree of vacuum and hence penetrability of X-rays could be changed by the operator. It utilized the principle that certain chemicals (caustic potash and potassium permanganate) liberated gases upon heating and absorbed them upon cooling. To facilitate alteration of vacuum, an accessory bulb was added to the main bulb and chemicals placed in the accessory bulb were heated to produce gas which reduced the vacuum in the tube. When the vacuum in the tube became high, resistance increased and the current supplying the tube was diverted to the low vacuum accessory bulb by means of adjustable wire. This resulted in heating of the caustic potash, which produced gas and caused the vacuum in the main tube to be lowered sufficiently to produce X-rays again.

In 1914, the accessory bulb was filled with asbestos, air was forced from the interstices of the asbestos as it was heated and the vacuum was reduced. Accessory bulb was later replaced by osmosis regulator. Osmosis regulator is based upon the principle that certain metals such as Palladium, when heated, became more porous to hydrogen.

Vacuum Tube

In an effort to eliminate the gas and stabilize the operation of X-ray tubes, J.E. Lilienfeld, an Austrian developed a tube in 1911 based on Field Current principles. The electrons were extracted from the cathode by using a high potential across the tube. The operation of such a cold cathode tube was described as "ticklish." Due the use of a curved cathode, charges became so crowded on the curved part that they easily leaked (Lilienfeld Effect). So, to increase the drain of electrons from the cathode the electrons were ejected from a pointed cathode.

In 1912, he applied for a US patent for a tube in which the cathode did not emit electrons that lowered the resistance of the tube and produced X-rays. But, the tube current was limited by this design. He was not able to heat the cathode enough.

Self-regulating Tubes

Self regulating tubes were developed by H.L. Sayew (1897). It had a second pair of electrodes embedded in potassium carbonate. When the vacuum within the tube rose too high, the current would arc between the electrodes, automatically heating the potassium carbonate, which in turn released a little gas and restored the efficient operation of the X-ray tube.

Demise of the Gas Tube (Fig. 1.9)

It was in 1907, that Clyde Snook installed his first X-ray machine. It was rated at 110 kVp. and 200 mA.

The real breakthrough in the tube design, which actually ushered in the '*golden age of radiology*' was the development of the hot cathode tube by William David Coolidge, (1913). Coolidge used a coil of tungsten as the source of electrons (as a filament-cathode) in the new 2 tubes which out- performed Lilienfeld's hot cathode tube. It permitted:

- Greater flexibility in the quality and quantity of X-rays produced.

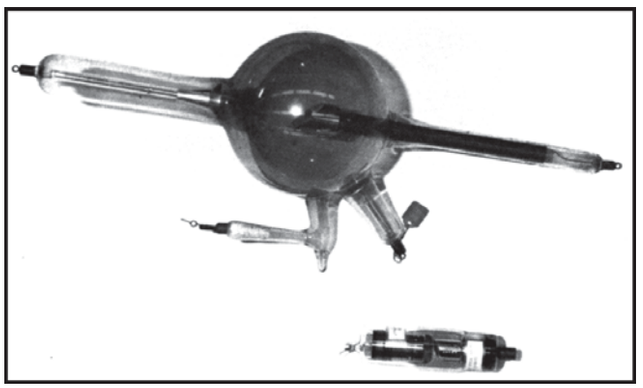


Fig. 1.9: Gas Regulated Tube (1902) in comparison with the modern X-ray tube

- Greater tube stability during the production of X-rays.
- Smaller tube size.
- Longer tube life.
- Direct operation from a transformer.

With the invent of the autotransformer, flexibility and reliability of the tube increased. An early problem with this new hot cathode tube was the conduction of heat away from the tungsten target. A tungsten anode backed by copper was found to be the most satisfactory method of dissipating heat rapidly, the heat was conducted to the radiation fins at the end of the tube or by circulating cold water through the anode stem.

Until 1918 all X-ray tube cooling was provided by means of air and water. Hirsh patented the idea of submerging the X-ray bulb in oil to effect greater cooling of the anode and tube. In 1919, Harry Waite submerged the tube and transformer as a single unit in the same oil bath.

In 1916, Coolidge self-rectified his old model. This particular tube was capable of operating with good efficiency when unrectified AC voltage was applied between the anode and cathode.

Shock Proof Dental X-ray Unit

The high voltage supply wires to the earlier tubes were uninsulated, open and unguarded as a result of which a number of dentists and patients were burned. In 1918-1919, prompted by this threat, Coolidge and General Electric Co. introduced the Victor CDX Shockproof Dental X-ray Unit (Fig. 1.10), which eliminated the exposed high tension wires. The principle of this design was to place the tube and high voltage components in an oil filled grounded compartment which acted as an electric insulator, coolant and radiation shield.

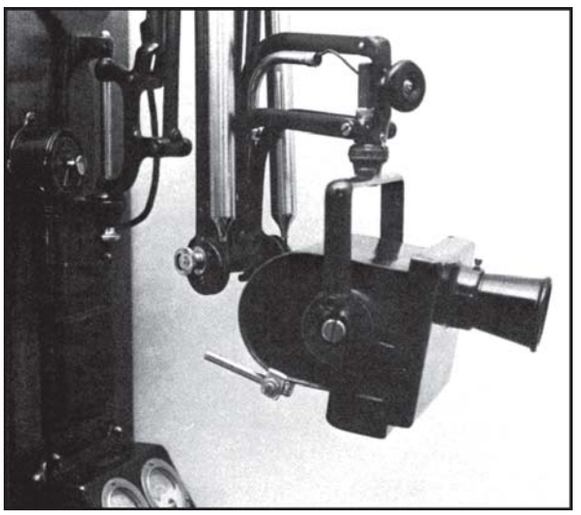


Fig. 1.10: Victor CDX – shock proof tube housing (1919)

The advantage of this tube was that the electric and fire hazard was eliminated. The anode and the tube length was reduced thereby permitting more rapid removal of heat, and the effect of altitude and humidity was also eliminated. Consequently many other improvement modifications were implemented, like:

- Focus tubes which used cup cathode in contrast to the earlier tubes in which an anode was placed perpendicular to the axis of the cathode rays.
- Water cooled targets.
- Line focussed tubes.
- Internal diaphragms.
- External veins on the anode to radiate heat.
- Broad focus tubes for therapy.

Adjustable Tube Stand

Early pioneers suspended the X-ray tube from the ceiling or from between the two clamps, one on either side of the bulb. The tube stand had extremely limited mobility.

Dr William Rollins (1896) designed an apparatus for use by dental profession exclusively. He was the first person to publish harmful effects of X-rays and constructed a protective device to shield the X-ray tube.

X-films

The first dental radiograph was taken on a small glass plate which had been cut to size from larger ones. These plates were preferred as they would not curl during development.

Kells and Rollins began to use the photographic film quite early because of its adaptability to tissues and its safety from breakage. Early films were hand-made and consisted of glass plates or roll films, cut to proper length and wrapped in black paper and rubber dam material to prevent moisture leakage. Their major disadvantage was lack of emulsion sensitivity.

In search for greater photographic sensitivity, early workers tried many bizarre and interesting methods. Many of them heated plates before exposure to decrease exposure time, and increase in fog with no increase in density of image resulted.

The first machine wrapped dental X-ray film packet, called Regular film (Kodak), became commercially available in1919. It was a single emulsion, relatively slow but produced sharp images. In the 1920's cellulose nitrate base was used which was highly inflammable and when burned, emitted large quantities of poisonous gases. In 1924, non-inflammable cellulose triacetate was marketed. But, it had a disadvantage as it was expensive, subject to mold, wrinkled and had a tendency to break, subsequently in the same year, the emulsion was placed on both sides which doubled the speed of the film, reduced exposure by fifty percent and reduced the tendency for the film to curl when it dried: Marketed as Radia-tized film (Kodak). In 1940, the Ultra speed (Improved Radia tized) films became available. In the 1960s, a film base of polyester (Dacron) was introduced and has been the material of choice, it has the advantage of being stronger, hence thinner films can be made and it does not tend to wrap. The Ekta speed film (Kodak), introduced in1980s has again reduced the exposure by 50 percent.

Evolution of the Darkroom

The most common early darkroom was the closet with or without running water, of the size three and a half feet by five feet. Developing times and solutions varied with the operator. Many of the early workers utilized a "four-bottled" photographic methods of development. The steps involved:

- Covering the sensitive material with a developing agent.
- Adding a preservative.
- Adding an accelerator.
- Adding a bromide.

In 1896, Kells described his radiographic technique as requiring a 5 to 15-minute exposure and a developing time of 30 to 60 minutes. He used tray development which required rocking the solution back and forth on a 'titubator' or by the operator, until the film was developed.

In 1909, tank development and standardized developing solution and procedures were introduced. Five-minute developing time at a temperature of 65° Fahrenheit was advocated. In 1918, Eastman Kodak Co. developed a darkroom with tank processing. Reliable film hangers became available in 1920's.

Automatic processors were introduced in the 1910's.

Growth of Dental Radiology

William Herbert Rollins (also known as the father of radiation protection) was trained in both dentistry and medicine, but mostly practiced dentistry. He developed new dental instruments, procedures, materials and many then in use. He also improved the camera, lenses, radios, made his own photographic film, built marine steam engines, etc. He was probably the first to suggest the use of radium for treatment of cancers. He warned against the dangers of X-rays and gave solutions to counteract the hazards. He was the first to urge the use of filters to remove the dangerous low energy X-rays. He introduced the collimator to reduce the beam size and recommended a long target film distance to improve image quality and patient safety. He advocated 'draping' the patient in 'non-radiable' material. He pioneered sandwiching the film between two intensifying screens to reduce exposure. He also suggested that Crooke's tube should be covered, except for the port, with radio-resistant material. Finally, he suggested that safe or harmless dose of radiation should be determined.

Kells in 1903 opened the first X-ray laboratory (The New Orlands X-ray Lab.). Work was confined to skiagraphs and fluoroscopic examination. He demonstrated radiograph of the chest, hip, a hand with a piece of brass shell in the thumb, a bullet in the head and measurement of the root canal. Some of the first stereoscopic radiographs were taken by Kells, and he was the person who introduced the paralleling technique in 1896.

Dr Weston A Price in 1904, introduced two techniques for film positioning in the oral cavity—the paralleling and the bisecting angle technique. He also developed the flexible leaded rubber, from which he manufactured the first pair of leaded gloves used by the radiologist. He was the person who established the relationship between nutrition and dental health.

In 1910, Franklin W McCormack, opened the first dental X-ray laboratory. In San Fransisco, he used a medical X-ray machine and a table instead of a chair for the patient. He used a longer target film distance.

In 1909, Howard Riley Raper, (a part time instructor at Indiana Dental College in Indianapolis), become interested in radiography and convinced the school's dean to purchase an X-ray machine. He was appointed as Professor of

radiology, and in 1909-1910, the first course of radiology was initiated by Raper. In 1911-1913, he published a series of papers in Dental Items of Interest which were subsequently (1916) gathered into the first textbook—Elementary and Dental Radiology. He has created a new discipline and a new name for it—RADIODONTIA. In 1918, he discovered the angle meter. This was mounted on the X-ray tube and used with a chart of vertical angles for various techniques to reduce distortions. In 1925, he introduced the bite-wing technique.

In 1940, Dr Gordon Fitzgerald designed a long cone for the dental X-ray machine. In 1949, the American Academy of Oral Roentgenology, (now known as American Academy of Dental Radiology) was formed.

The rotational panoramic radiography method is by far the most popular method of panoramic radiography. Dr H Numata (Fig. 1.11A) was the first to propose (1933) and experiment (1934) with this method of panoramic radiography. Numata placed a curved film in the mouth lingual to the teeth and used a slit or narrow X-ray beam that rotated around the patient's jaws to expose the film Figs 1.11B and C). Twelve years later, in 1946 Y.V. Paatero (Fig. 1.12) of the Institute of Dentistry, Finland, proposed (1946), experimented (1948) and demonstrated a slit beam method of panoramic radiography for the dental arches (1949). In 1960s, S.S. White and Company marketed the first Panoramic machine (Panorex). In 1968, the International Association of Dento-Maxillofacial Radiology was established.

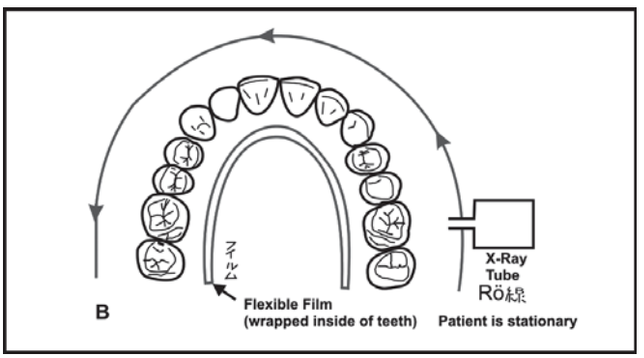


Fig. 1.11B: Diagram of panoramic technique used by Dr Numata

Fig. 1.11C: Mandibular radiograph taken by Numata's method

Fig. 1.11A: Dr H.Numata. First to take panoramic radiograph of teeth in 1933

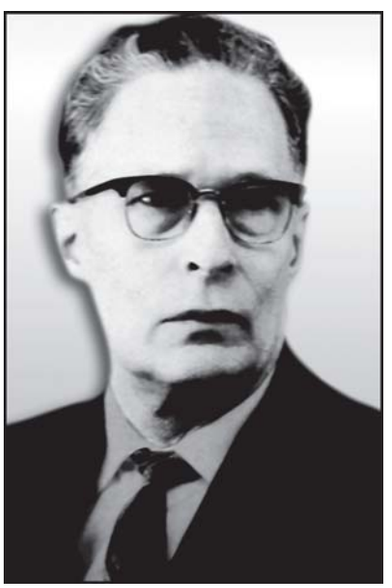


Fig. 1.12: Dr Y.V. Paatero. The father of Panoramic Radiography

Table 1.1: Highlights in the History of Dental Radiology

Years	*Concepts*	*Persons associated with*
1895	Discovery of X-rays	W.C. Roentgen
1896	First dental radiograph	O. Walkhoff
1896	First dental radiograph in US (skull)	W.J. Morton
1896	First dental radiograph in US (live)	C.E. Kells
1901	First paper on dangers of X-radiation	W.H. Rollins
1904	Introduction of bisecting technique	W.A. Price
1913	First dental text	H.R. Raper
1913	First prewrapped dental films	Eastman Kodak Company
1913	First X-ray tube	W.D. Coolidge
1920	Concept of paralleling technique	F. McCormack
1920	First machine-made film packets	Eastman Kodak Company
1923	First dental X-ray machine	Victor X-ray Corporation of Chicago
1925	Introduction of bite-wing technique	H.R. Raper
1933	Concept of rotational panoramics proposed	Dr Hisatugu Numata
1947	Introduction of long cone paralleling technique	F.G. Fitzgerald
1948	Introduction of panaromic radiography	Dr Yrjo Veli Paatero
1955	Introduction of D-speed film	
1957	First variable kilovoltage dental X-ray machine	General Electric
1960	First panoramic X-ray machine marketed	S.S. White and Co.
1978	Introduction of dental xeroradiography	
1981	Introduction of E-speed film	
1987	Introduction of intraoral digital radiography	

BIBLIOGRAPHY

1. Goaz DW, White SC. Oral Radiology, Principles and Interpretation. 2nd, CV Mosby, 1987;1-17.
2. John W. Preece, Roentgen Alchemy Part I and II, Modern Radiology in Historical Perspective. Springfield, Ill, Charles C. Thomas, Publisher. 1962;22.
3. Mc Call, JO and Wald, SS. Clinical Dental Roentgenology. Philadelphia, 1947, WB Saunders Co.
4. Mc Coy JD. Dental and Oral Radiology. St. Louis, The CV Mosby Co. 1919.
5. Taylor JA. History of Dentistry. Philadelphia, 1922, Lea and Febiger.

Section Two
Physics of Ionizing Radiation

2

Radiation Physics

BASIC CONSIDERATIONS

The world is composed of matter and energy.

Matter is the substance of which all physical things are composed, it occupies space, has inertia, mass can exert force and can be acted upon by force. It occurs in three states, solid, liquid and gaseous and may be divided into elements and compounds, which are essentially made of molecules and atoms.

When matter is altered, *energy* results.

An *element* is made up of an accumulation of a single species of atoms.

A *compound* is made up of recurring units of atoms, in a definite arrangement with at least two of the atoms being different.

An *atom* is the fundamental unit of any particular element, which cannot be subdivided by an ordinary chemical methods, but may be broken down into subatomic particles by a special high energy techniques.

A *molecule* is the smallest particle of a compound.

The atom consists of two parts, a central nucleus and orbiting electrons. The identity of an atom is determined by the composition of its nucleus and the arrangement of its orbiting electrons (Fig. 2.1).

The *nucleus*, or the dense core of the atom is composed of particles known as *protons* and *neutrons* (nucleons); protons carry the positive electrical charges, whereas neutrons carry no electrical charge. The nucleus of the atom occupies very little space. Atoms differ from one another based on their nuclear composition. The number of protons and neutrons in the nucleus of an atom determines its *mass number* or *atomic weight*. The number of protons inside the nucleus equals the number of electrons outside the nucleus and determines the atomic number of the atom. Each atom has an atomic number ranging from that of Hydrogen, the simplest atom, which has an atomic number of 1, to that of Hahnium, the most complex atom, which has an atomic number of 105. Atoms are arranged on an increasing atomic number on a chart known as the *periodic table of elements*.

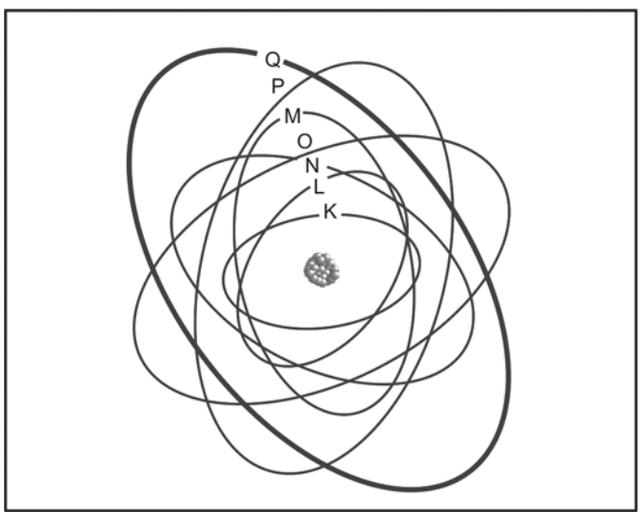


Fig. 2.1: Atom showing structure and identification of electron shells around the nucleus

Electrons are tiny negatively charged particles that have very little mass; an electron weighs approximately 1/1800 as much as a proton or neutron. The arrangement of the electrons and neutrons in an atom resemble that of a miniature solar system. Just as the planets revolve around the sun, electrons travel around the nucleus in well defined paths known as *orbits* or *shells*.

An atom contains a maximum of seven shells, each located at a specific distance from the nucleus and representing different energy levels. The shells are designated with the letters K,L,M,N,O,P, and Q; the K shell is located closest to the nucleus and has the highest energy level, and has a quantum number 1, and Q which is the farthest has the quantum number 7. Each shell has a maximum number of electrons it can hold, which is determined by the formula, $(2n)^2$, where n is the quantum number.

Electrons are maintained in their orbits by the *electrostatic force*, or attraction, between the positive nucleus and the negative electrons, and it also balances the centrifugal force of the rapidly moving electrons. This is known as the *binding energy* or binding force of an electron. This binding energy is determined by the distance between the nucleus and the orbiting electrons and is different for each shell. The strongest binding energy is found closest to the nucleus in the K shell, whereas electrons located in the outer shell have a weak binding energy. The binding energies of orbital electrons are measured in *electron-volts* (eV) or *kilo-electron volts* (keV). (one keV equals 1000 eV).

The energy required to remove an electron from its obital shell must exceed the binding energy of the electron in that shell. A great amount of energy is required to remove an inner shell electron, but electrons loosely held in the outer shells can be effected by lesser energies. For example, in the tungsten atom, the binding energies are as follows:

- 70 keV K shell electrons
- 12keV L shell electrons
- 3 keV M shell electrons

Thus in this case to remove a K shell electron from a tungsten atom, 70 keV (70,000 eV) of energy would be required, whereas only 3 keV (3,000 eV) of energy would be necessary to remove an electron from the M shell.

Atoms combine with each other to form *molecules*. A molecule may be defined as two or more atoms joined by chemical bonds, or the smallest amount of substance that possesses its characteristic properties. Molecules are formed in one of the two ways—by the transfer of electrons, or by the sharing of electrons between the outer most shells of the atoms.

Atoms can exist in a neutral or an electrically unbalanced state. Normally, most atoms are neutral. A neutral atom consists of an equal number of protons and electrons. An atom with an incompletely filled outer shell will attempt to capture an electron from an adjacent atom. If the atom gains an electron, it has more electrons than protons and therefore has a negative charge, and if the atom loses an electron, it will have less electrons than its protons and therefore has a positive charge. An atom that gains or loses an electron and becomes electrically unbalance and is called an *ion*.

Ionization (Fig. 2.2) is the production of ions, or the process of converting an atom into ions. Ionization deals with electrons only and requires sufficient energy to overcome the electrostatic force that binds the electron to the nucleus. When an electron is removed from an atom in the ionization process, an *ion pair* results. The atom becomes a positive ion, and the ejected electron becomes the negative ion. This ion pair reacts with other ions until electrically stable, neutral atoms are formed.

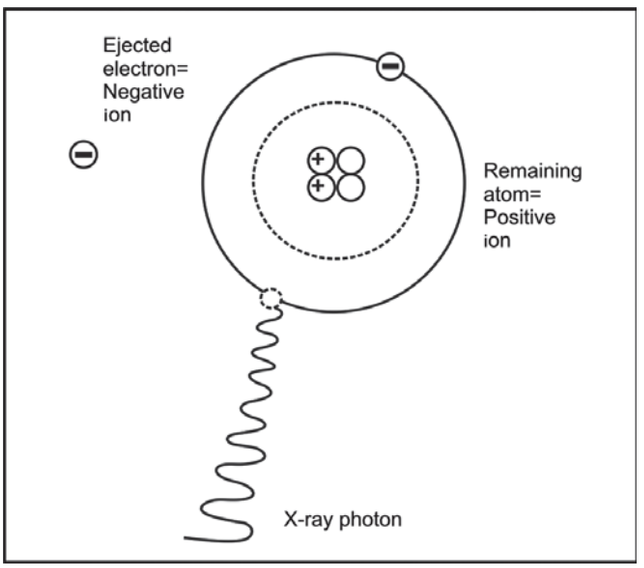


Fig. 2.2: An ion pair is formed when an electron is removed from an atom; the atom is the positive ion and the ejected electron is the negative ion

Just as an electron has to receive energy to escape from its orbit, so when it transfers from one orbit to another closer to the nucleus it must surrender some energy. It has to in fact, give up the difference between the binding energy of the two orbits and this energy is emitted in the form of *electromagnetic radiation*.

The binding energy of different orbits depends on the nucleus charges and therefore will be different for different elements, further more, the difference between the binding energy will vary from element to element and so will the energy of the radiation emitted following ionization. The energy level values and their difference are characteristic of the element and thus the radiation emitted constitutes a *line spectrum* and are usually called the *characteristic radiation* of the element.

The process of raising an electron to a higher level is called *excitation*. Many a times no electron is lost by the atom but one electron is raised into an unstable orbit and ultimately returns to its normal state with the emission of radiation, characteristic of the atom concerned. When the atom is in an "excited" state it is often more chemically reactive than normal, thus excitation may enable it to take part in a chemical process into which in a normal state it would not enter. *Excitation in biological material is an important cause of biological damage caused by radiation*.

Ionization is usually followed by emission of X-radiations; and excitation is followed by the emission of visible or ultraviolet radiations.

ELECTROMAGNETIC SPECTRUM

Energy is defined as the ability to do work. There are different types of energies:

1. *Kinetic energy*: It is that energy produced by virtue of movement.
2. *Potential energy*: It is that energy that a body has by virtue of its position, e.g. a coiled spring.
3. *Heat energy*: It is the movement of atoms and molecules of any material. The level of heat is indicated by temperature. An increase in temperature causes increased movement of the particles and hence an increase in their energy.
4. *Electrical energy*: It is that energy that is measured by multiplying the electric charge being moved by the electrical force (voltage or potential difference) against which it has been moved. It is the product of the current (amperes), the pressure (volts) and time (hours). The unit is known as kilo watt hour.

   In radiology the electrical charge is electrons (e), unit of energy is electron volt (eV) or kilo electron volt (keV), which is the energy involved when an electron passes through a potential difference of 1000 volts.
5. *Chemical energy*: It is that energy locked up in chemical compounds and released under certain circumstances, e.g. explosives.
6. *Nuclear energy*: It is that energy that is locked up in the heart of the nucleus of an atom also called as "atomic energy."
7. *Radiation energy*: It is that energy which is released during the process of ionization or excitation of an atom.

Radiation is defined as the emission and propagation of energy through space or a substances in the form of waves or particles.

Radioactivity is defined as the process by which certain unstable atoms or elements undergo spontaneous disintegration or decay, in an effort to attain a more balanced nuclear state.

Ionizing radiation can be defined as radiation that is capable of producing ions by removing or adding an electron to an atom. This is further classified into two types:

i. *Particulate radiation*: These are tiny particles of matter that possess mass and travel in straight lines and at high speeds. Particulate radiations transmit kinetic energy by means of their extremely fast-moving, small masses.

   Four types of particulate radiations are recognized:
   - *Electrons* which may be classified as beta particles or cathode rays. They differ in origin only.
     a. *Beta particles* are fast moving electrons emitted from the nucleus of radioactive atoms.
     b. *Cathode rays* are streams of high speed electrons that originate in an X-ray tube.
   - *Alpha particles* are emitted from the nuclei of heavy metals and exist as two protons and neutrons, without electrons.
   - *Protons* are accelerated particles, especially hydrogen nuclei, with a mass of 1 and a charge of +1.
   - *Neutrons* are accelerated particles with a mass of 1 and no electric charge.

ii. *Electromagnetic radiation* can be defined as the propagation of wave like energy (without mass) through space or matter. The energy that is propagated is accompanied by an oscillating electric and magnetic fields positioned at right angles to one another. These are man made or occur naturally. Electromagnetic radiations are arranged according to their energies in what is termed *electromagnetic spectrum*.

   Electromagnetic radiations are believed to move through space as both a particle and a wave; hence an explanation of the characteristics of electromagnetic radiation requires *a dualistic theory*:

   a. *Wave theory*: It states that radiation is propagated in the form of waves, and focuses on the properties of velocity, wave length, frequency and amplitude.

      Velocity (c) refers to the speed of the wave. All electromagnetic radiations travel as waves or a continuous sequence of crests at the speed of light. (3×10^8 meters/per second [186,000 miles per second]) in a vacuum.

      Wave length (λ) can be defined as the distance between the crest of one wave and the next. Wave length determines the energy and penetrating power of the radiation; the shorter the distance between the crests, the shorter the wave length and higher the energy and ability to penetrate matter. Wave length is measured in nanometers (1×10^{-9} meters or one-billionth of a meter) for short waves and in meters for long waves.

      Frequency (ν) is the number of waves that pass a given point in a certain amount of time. Frequency and wave length are inversely related; if the frequency of the wave is high, the wave length will be short, and if the frequency is low the wave length will be long. The unit of measurement of frequency is Hertz.

The amount of energy in an electromagnetic radiation depends on the wave length and frequency.

Low frequency electromagnetic radiations have a long wave length and less energy, and, conversely, high frequency electromagnetic radiations have a short wave length and more energy.

Amplitude is the maximum displacement of the wave from rest point.

The above parameters are related by the formula $\nu = hc/\lambda$ where h is a plank's constant, which is 6.61×10^{-34} Joules/second.

Wave theory accounts for the property of refraction, reflection, diffraction, interference and polarization.

b. *Quantum theory*: This particle concept characterizes electromagnetic radiations as discrete bundles of energy called *photons* or *quanta*. Photons are bundles of energy with no mass or weight that travel as waves at the speed of light and move through space in a straight line, "carrying the energy" of electromagnetic radiation. The unit of photon energy is eV or E, where $E = h\nu$

we know that $C = \lambda\nu$

therefore $E = hc/\lambda$

c is velocity, which is also constant,

therefore, $E = 1/\lambda$

Properties of Electromagnetic Radiations

1. They travel through space in a wave motion along a straight line.
2. They have neither mass nor weight nor electrical charge.
3. They travel at the speed of light, in a vacuum i.e. 3×10^8 m/sec or 186,000 miles/second.
4. As they travel through space they give off an electric field at right angles to the path of propagation and a magnetic field at right angles to both (the path of propagation and electric field) (Fig. 2.3).
5. They transfer energy from place to place in quanta (photons).
6. In passing through matter the intensity of radiation is reduced (attenuation) both because energy is taken up by the material (absorption) and some energy is deflected from its original path to travel in a new direction (scattering).
7. In free space the electromagnetic radiation obey the inverse square law, which states that, for a point source, the radiation intensity (I) at any place varies inversely as the square of the distance (d) from the source to the place at which the intensity is being considered. $I = k/d^2$ where k is a constant, $I = 1/d^2$ (Fig. 2.4).
8. All electromagnetic radiations have a measurable but different temperature and energy, (frequency and wave length).
9. All electromagnetic radiations are invisible to the naked eye, with the exception of those falling within the range of the visible spectrum.

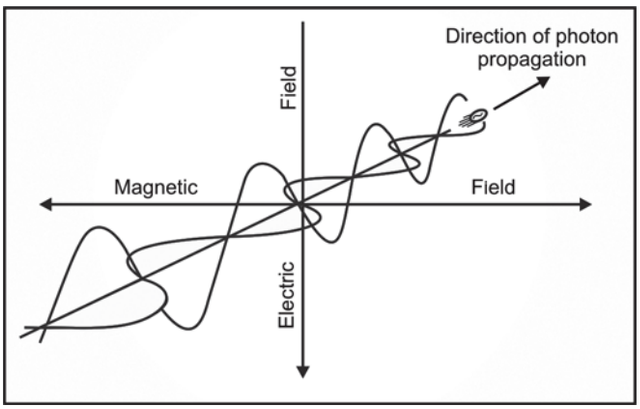


Fig. 2.3: Scheme of electromagnetic radiation illustrating electric and magnetic fields associated with photon

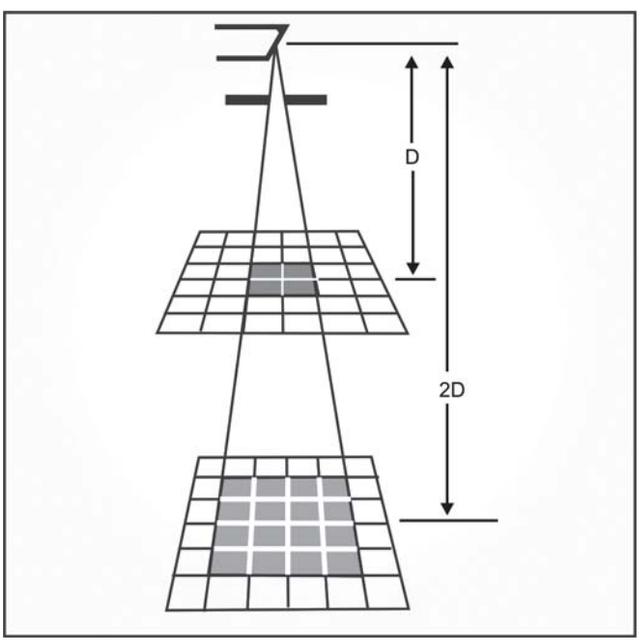


Fig. 2.4: The Inverse Square Law states that the intensity of radiation is inversely proportional to the square of the distance from the source. In the given diagram as the source to film distance is doubled, the intensity of radiation is 1/4th as intense

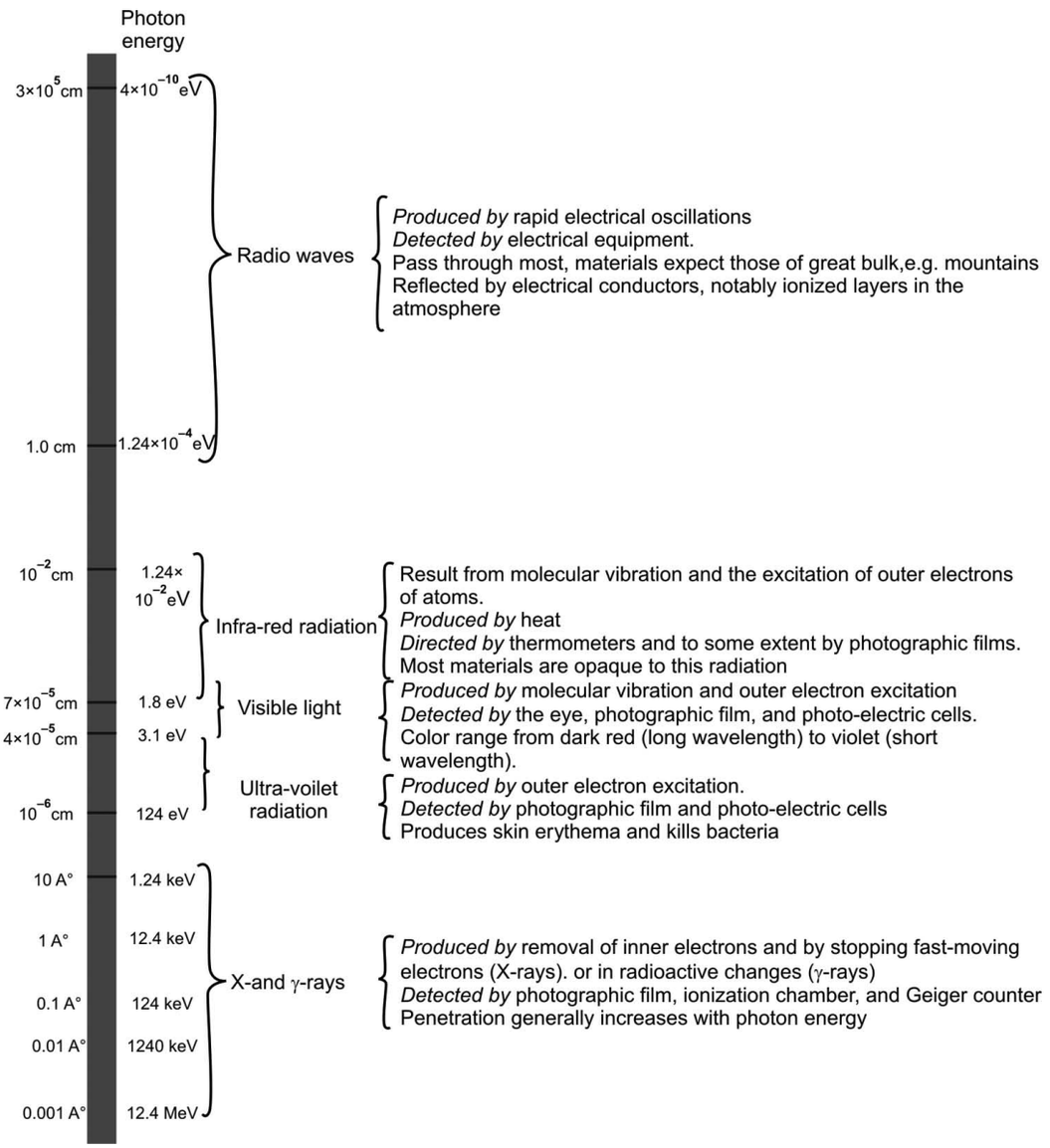


Fig. 2.5: Diagrammatic representation of the EMS

MAIN TYPES OF RADIATIONS WHICH COMPRISE THE E.M.S. (FIG. 2.5)

Electric waves these have the longest wave length, 10^{15}A°.

Hertzian waves these waves are used by high altitude transmission satellites, and have a wave length of 10^{16}A°–10^{13}A°.

Communication waves or *Radio waves* these waves can pass through most materials except that of great bulk. The wave length varies from 10^{13}A° – 10^{8}A°.

The experiments by Hertz, Maxwell and Henry Faraday and the invention of the telegraph by Marconi were key steps to the understanding the application of these radiations.

Uses

i. Medicine—radio waves are used to transmit the pattern of the heartbeat through a monitor at a patient's home to a near by hospital.
ii. Others—the prime purpose of radio waves is to convey information from one place to another through the intervening media (air, space, nonconducting materials) without wires. This is applied in the transmissions of the radio, television, and radar.

Radio range, radio compass and radio time signals are used for navigation of ships and air crafts.

Various remote control devices, including rocket and artificial satellite operations systems and automatic valves in pipelines are activated by radio signals.

The development of the transistor and other micro-electronic devises led to the development of portable transmitters and receivers. Cellular and cordless telephones are actually radio transreceivers.

Some celestial bodies and interstellar gases emit relatively strong radio waves that are observed with radio.

Telescopes composed of very sensitive receivers and large directional antennas.

Short wave diathermy or microwaves these have wave lengths from 3×10^{-2}m to 3×10^{-4} m, these overlap the wave lengths of the communication waves on one end and infra red waves on the other end.

Uses

i. These wave are used to transmit information to satellites.
ii. Mobile phones work on these microwaves.
iii. They are used in microwave ovens.
iv. These waves can penetrate tissues and cause moisturized molecules in cells to vibrate resulting in internal friction and increase in temperature of affected cells.
v. The therapeutic uses are:
   In ophthalmology
   - Treatment of sinusitis.
   - In selected cases of cancer therapy.
   - In oral surgery, to reduce postoperative swelling and trismus arising from traumatic procedures.

Infra-red waves these have wave lengths ranging from 40,000A° to 1,00,000A°. These occupy the part of the spectrum with a frequency less than that of visible light and greater than that of radio waves. The name infra-red means "below the red."

These were discovered in 1800 by Sir William Herschel, who was attempting to determine that part of the visible spectrum with the minimum associated heat in connection with astronomical observations he was making.

This radiation results from molecular vibration and excitation of outer electrons of atoms. It comprises of that portion of sunlight which the body feels as heat. It is also emitted by an electric bulb or heating coil.

Uses

i. To study cloud structure.
ii. The temperature of a distant object can be determined by analysis of the infra-red radiation from the object.
iii. Radiometers operating in the infra-red range serve as the basis for many instruments, including heat seeking devices in missiles and devices for spotting and photographing persons in the dark or fog.
iv. Infra-red astronomy.
v. Medicinal uses of infra-red radiation range from the simple heat lamp to technique of thermal imaging or thermography, which is also used in industry.
vi. In dentistry: It is used for tooth vitality testing, surgical diathermy, altering properties of dental materials like wax, gutta percha, and for curing acrylic.

Humans may not be able to see infrared light, but snakes in the pit viper family, like rattle snake, have sensory "pits", which are used in image infra-red light and this allows the snake to detect warm blooded animals, even in dark burrows.

Visible light this ranges from 4,000 A° to 7,700 A°. The range of color is often called VIBGYOR,with red having the longest wave length and violet having the shortest wave length. R—red, O—orange, Y—yellow, G—green, B—blue, I—indigo, V—violet.

In 1672, Isaac Newton produced dispersion into the colors of the visible light spectrum. And in the early 1900's Thomas Young demonstrated that light suffered interference, and that a double source of light can give an interference-generated fringe pattern of bright and dark bands. The source of this visible light is the sun and from sparks, heated metal and filaments in lamps.

Uses

i. In optical fibers.
ii. In dentistry it is used in dental photography and operative field illumination.

Ultra-violet light this ranges from 1,000A° to 2,000A°. The beneficial effects of sunlight has been recognized for centuries, as evidenced by the sun bathing cults of the Egyptians and Babylonians, and the sun worshiping Incus. In the 19th century, Neil Finsen proved that UV rays caused sun burn and Finsen et al in 1902 recognized the beneficial and bactericidal effects of UV on TB bone. They can also be produced from incadescent lamps. These rays have a slight penetrating power (up to density of quartz) and can penetrate living tissues for a depth of a few millimeters and cause biological effects like:

1. Photo erythema (sun burn).
2. Photo pigmentation (sun tan).
3. Photo chemical cornification of skin and skin carcinoma (malignant dermal changes).

4. Bactericidal effect.
5. Aging of skin.
6. Eyes are sensitive to UV rays which can cause cataract or keratitis.
7. Is an agent in the production of vitamin D.

The ultra-violet spectrum can be divided into three groups based on the wave lengths:

1. Between 200 and 290 nm, short or germicidal UV rays or UVC, these can cause genetic mutations, altered reproductive cycles and cell death.
2. Between 290 and 320 nm, middle or erythemal UV rays or UVB, these can cause skin erythema and are commercially available as sun or mercury vapor lamps.
3. Between 320 and 380 nm, long or black light UV rays or UVA, on its own it is not damaging but when used with sensitizing chemicals, it can cause extensive biological damage.

Uses

i. It can be used in photography, as it can darken photographic emulsion.
ii. It has the property of fluorescence, and is used in paints, dyes, lighting.
iii. In dentistry it is used to:
   - Disclose plaque or unclean surfaces by fluorescence.
   - Photo polymerization of composite used for:
     – Fissure sealing.
     – Fixing orthodontic brackets.
     – Splinting teeth.
     – Placing pontics in temporary bridge work.
     – Restoring teeth.
     – Repairing facings, etc.

It is interesting to note that ultraviolet rays are not visible to the human eye but certain insects like the bumble bee can see them!!!

X-rays were first observed and documented in 1895 by Wilhelm Conard Roentgen, a German scientist who found them quite by accident, since then there has been a virtual revolution in the field of Medicine. X-rays have a wave length from 1 to 2 A° to 0.001A°, many things in space emit X-rays—black holes, neutron stars, binary star systems, supernova remnants, stars, the sun, comets, etc. They are also produced in the X-ray tube by removal of the inner electrons, and are detected by photographic film, ionization chamber and Geiger Counter.

X-rays are divided into four type depending on their wave lengths:

- 1-2 A°—Grenz or Super Soft X-rays, mainly used to treat superficial lesions and in crystalogy.
- 1-0.5A° Soft X-rays, mainly used in contact therapy.
- 0.5-0.1 A°—Medium X-rays, mainly used in diagnostic and superficial therapy.
- 0.1 A°—Hard X-rays, mainly used for deep X-ray therapy and for industrial roentgenography.

The other general uses of X-rays are: Its property of fluorescence is used in medicine for fluoroscopic examination and intensifying screens in extra oral radiography.

- Radiography and monitoring film badges.
- To sterilize commercial items in bulk.

Gamma rays are high powered X-rays, having a wavelength of 0.001A°. These are electromagnetic radiations, but their source is from the radioactive decay process. They have shorter wave length and greater penetrating power and are used in the treatment of tumors, e.g. Radon needles or seeds which are implanted at the tumor site, radioactive iridium in nylon threaded seeds, percutaneous radiotantalum wire implants, etc.

Cosmic rays these have the shortest wave length, 0.0001A°. A cosmic ray is a high speed particle—either an atomic nucleus or an electron—that travels throughout the Milky Way Galaxy, including the solar system.

Some of these particles originate from the sun, but most come from sources outside the solar system and are known as galactic cosmic rays, (GCR). Cosmic ray particles that arrive at the top of the earth's atmosphere are termed the primaries; their collisions with atmospheric nuclei give rise to secondaries. They effect the earth's magnetic field. They played a critical role in the scientific study of atomic nucleus and its components.

Each radiation type tends to overlap the juxtaposed neighboring radiation so that there is no precise cut-off boundary for any type of radiation.

Laser (Light Amplification by Stimulated Emission of Radiation) is a device which can operate in the infra-red, visible or ultra-violet region of the spectrum and which amplifies electromagnetic waves by stimulated emission of radiation.

When atoms or molecules absorb energy they can emit light spontaneously or they can be stimulated to do so by a light wave. If a body of atoms is raised to the excited state by pumping, then an incident light wave will stimulate photon emission and net amplification of the incident light beam results. The output is extremely powerful and mobilizes intense heat at close range as the atoms are stimulated to emit photons at an infinitely greater rate than would spontaneously.

Laser light has four characteristics that distinguish it from the light produced from other sources, like the electric bulb and the sun. These are:

- Laser light is highly directional and travels in a narrow beam, the sides of which stay almost parallel.
- Laser produces coherent light, that is it has only one frequency.
- Laser light is of a single color.
- Laser light is very bright, powerful with very high intensity.

The laser concentrates and amplifies the light to give a concentrated beam of energy which can melt metals and drill holes in them. Laser beams can be used to make very accurate measurements of distance, perform delicate surgical procedures involving the eye and are used in compact disk players to convert the patterns on the disk into sound.

Medicine has benefited considerably from using lasers. They replaced many conventional techniques, which have lead to shorter periods of treatment, reduced blood loss due to the laser's ability to seal blood vessels, less postoperative infection and the fact that difficult, often inaccessible regions of the body can be reached more easily.

In dentistry the patients suffer less pain since drills are not used. Treatments carried out include curing of fillings, excision of soft tissue growths and repair and reshaping of damaged teeth.

BIBLIOGRAPHY

1. Barr JH, Stephens RG. The Physics of X-rays. Dental Radiology: Pertinent Basic Concepts and their Applications in Clinical Practice. Philadelphia, WB Saunders 1980;1-8.
2. Interact with English Main Course Book. Secretary, CBSC, New Delhi 2004;52.
3. Kasle MJ, Langlais RP. Basic Principles of Oral Radiography Exercises in Dental Radiology. Vol. 4 Philadelphia, WB Saunder 1981;2-36.
4. Kelsey CA. Atomic and Molecular Structure. Essentials of Radiology Physics. St Louis, Warren H Green 1985;34-42.
5. WJ Merdith, JB Massey. Fundamental Physics of Radiology. Second edition, Bristol: John Wright and Sons 1972.

3

Properties of X-Rays

DEFINITION

X-rays are defined as weightless packages of pure energy (photons) that are without electrical charge and that travel in waves along a straight line with a specific frequency and speed.

The properties of X-rays may be classified into four broad categories:

A. Physical
B. Chemical
C. Biological
D. Physiochemical.

Physical Properties

1. X-rays belong to a family of electromagnetic radiations having a wavelength between 10 A° to 0.01 A°.
2. They travel through space in a wave motion.
3. In free space they travel in a straight line.
4. They travel with the same speed as that of visible light (i.e. 1,86,000 miles per second).
5. As they travel through space, they can produce an electrical field at right angles to their path of propagation and a magnetic field at right angles to the electric field.
6. They are invisible to the eye and cannot be seen, heard or smelt (they remain undetected by the human senses).
7. They cannot be focused by a lens.
8. They cannot be reflected, refracted or deflected by a magnet or electric field as they do not possess any charge.
9. They show the properties of interference, diffraction and polarization, similar to that of visible light.
10. They do not require a medium for propagation.
11. X-rays are pure energy, no mass and they transfer energy from place to place in the form of quanta (photons). ($E = h\nu$).
12. In free space they obey the inverse square law, which states that for a point source of radiation the intensity (I) at any given place varies inversely as the square of the distance (d) from the source to the place at which the intensity is being considered.

    $I=1/d^2$ or $I=k/d^2$ where k is a constant.

    Intensity is determined by the number or quantity of X-ray photons in a beam.
13. X-rays are produced by the collision of electrons with tungsten atoms. The collisions which occur are of two types, thus giving rise to two types of spectra (Fig. 3.1):
    i. Continuous Spectra (General Radiation, Bremsstrahlung Radiation or Braking Radiation) (Fig. 3.2).

    The incoming electron penetrates the outer electron shell and passes close to the nucleus of the tungsten atom. The incoming electron is dramatically slowed down and deflected by the nucleus with a large loss of energy, which is emitted in the form of X-rays. The amount of deceleration and the degree of deflection determines the amount of energy lost by the bombarding electron and hence the energy of the resultant emitted photon has a wide range or spectrum of energies and therefore called Continuous Spectrum.

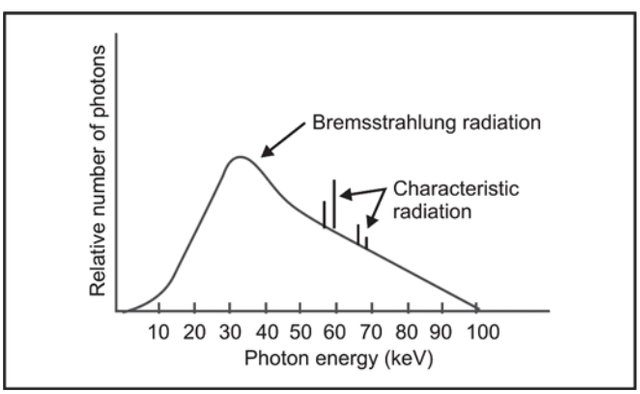


Fig. 3.1: Spectrum of photons emitted from X-ray beam generated at 100 kVp. Note vast preponderance of Bremsstrahlung radiation with minor addition of characteristic radiation

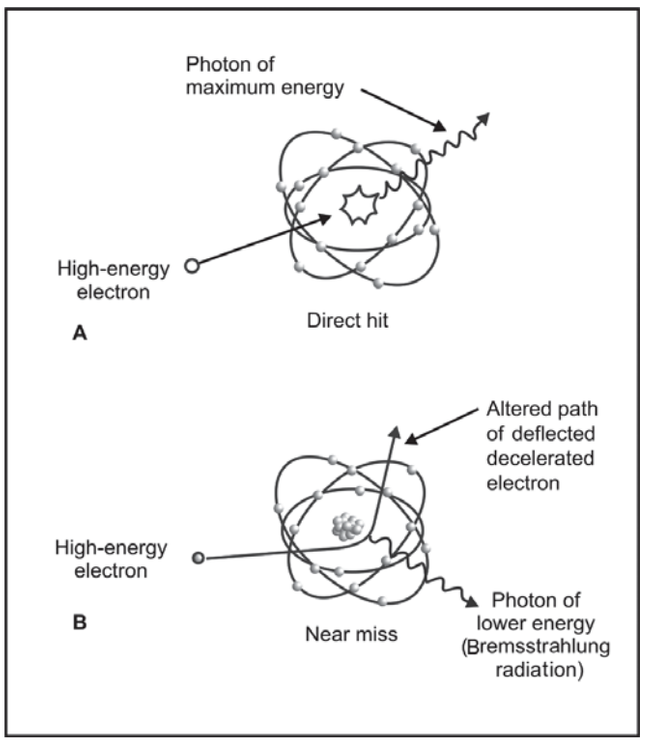


Fig. 3.2: Bremsstrahlung radiation is produced by direct hit of electron by nucleus in target mA or by the passage of electrons near the nucleus, which results in electrons being deflected and decelerated

ii. Characteristic Spectrum or Line Spectrum (Fig. 3.3): The incoming electron collides with an inner shell tungsten electron, displacing it to an outer shell (excitation), or displacing it from the atom (ionization), with a large loss of energy and subsequently the orbiting tungsten electrons rearrange themselves to return the atom to neutral or ground state. This involves electron 'jumps' which results in the emission of X-ray photons with a specific energy called Characteristic Spectrum.

14. X-rays can penetrate various objects and the degree of penetration depends upon the quality of the X-ray beam, and also on the intensity and wavelength of the X-ray beam.

Quality is defined as the energy carried by the X-ray beam. The quality of the X-ray beam is determined by the kilo voltage, milli amperage, distance between the target and the object, time or length of exposure, filteration and target material.

The wavelength (Fig. 3.4) is related to frequency (Fig. 3.5) by the formula $\lambda\nu = c = 3 \times 10^8$ m/sec, where λ = wavelength in meters, ν = frequency in cycles/seconds (Hertz), c= velocity which is a constant.

Therefore, $\nu = 1/\lambda$,

if there is increase in kilovoltage, wavelength will decrease, penetration will increase.

$E = hc/\lambda = 12.4/\lambda$, where E is energy, h is planks constant and c is a constant for all electromagnetic radiations.

The wavelength of X-rays range from;

- 1-2 A°: Grenz or Super Soft X-rays.
- 1-0.5 A°: Soft X-rays.

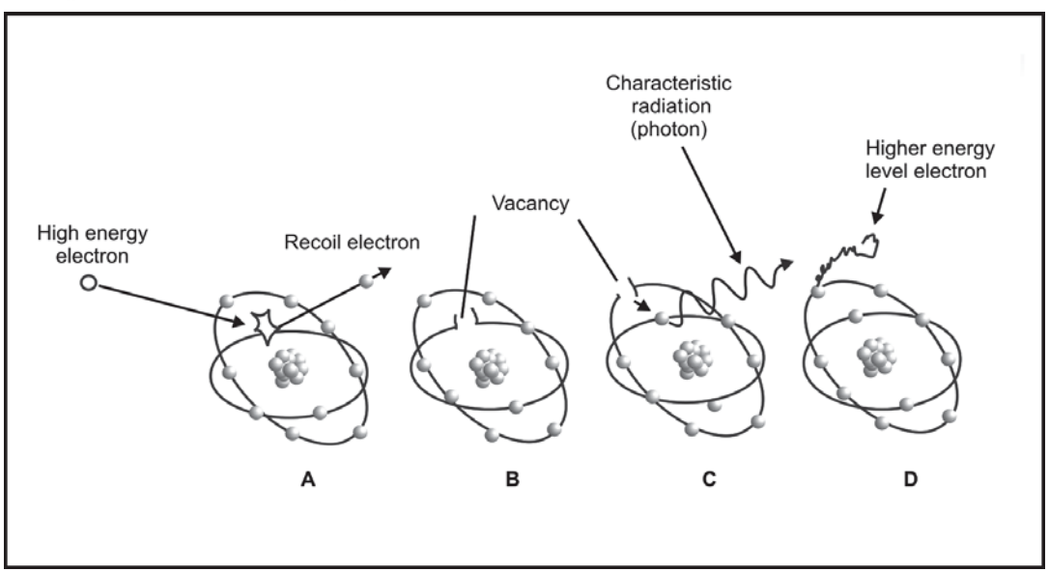


Fig. 3.3: Characteristic radiation. A. Incident electron ejects photoelectron from inner orbit, creating vacancy. B. Inner vacancy is filled with electron from outer orbit. C. Photon is emitted with energy equal to the difference in energy levels of two orbits. D. Electrons from various orbits may be involved, giving rise to other photons. Energies of photons thus created are characteristic of target atom

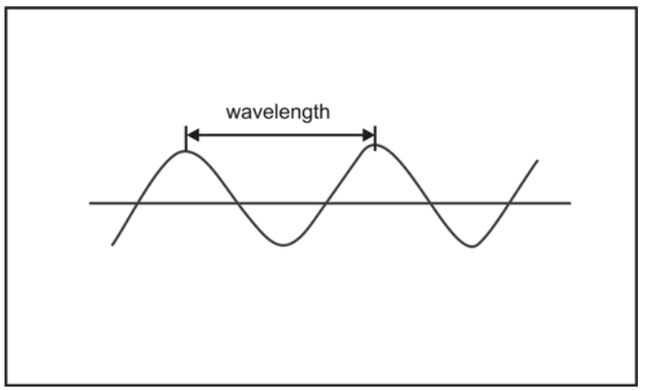


Fig. 3.4: Wavelength is the distance between the crest (peak) of two consecutive waves

- 0.5-0.1 A°: Medium X-rays.
- 0.1 A°: Hard X-rays.
- 0.001 A°: Gamma rays or high powered X-rays.

X-rays can penetrate and pass through many solids which are opaque to light, e.g. wood, flesh, but X-rays cannot penetrate through heavy metals and bones and therefore cast a shadow of these objects when placed in their path.

This property of penetration helps in diagnosing various lesions and in the treatment of malignant lesions.

15. Property of attenuation, absorption and scatter; when passing through matter the intensity of radiation is reduced (attenuation) both because radiation energy is taken up by the material (absorption) and some is deflected from the original path, to travel in a new direction (scattering).

    Attenuation depends upon;

    a. Thickness of the object: Thickness increases, attenuation also increases.
    b. Atomic number or density of the object: Atomic number increases, density increases, attenuation also increases.

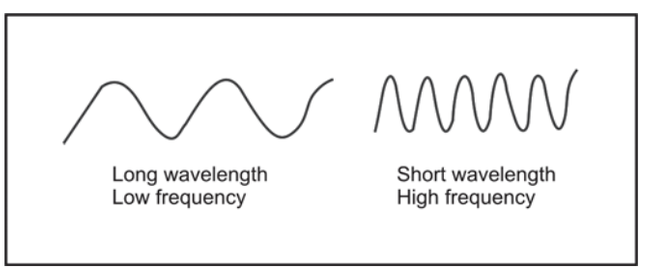


Fig. 3.5: Frequency is the number of wavelengths that pass a given point in a certain amount of time. The shorter the wavelength, the higher the frequency, and vice versa

    c. Photon energy of the electron: Photon energy increases, there will be decrease in attenuation for the given object.

    Absorption when passing through any object the X-rays are differentially absorbed (i.e. there is conversion of their kinetic energy into energy of the absorber electrons). The degree of absorption depends on the atomic structure or density of the matter and the wavelength of the X-rays (Fig. 3.6) (Table 3.1).

Table 3.1: Components of the body arranged in order of their power to absorb X-rays, starting from the lowest value

1.	Air
2.	Fat
3.	Soft tissues, blood, body fluids
4.	Medullary bone
5.	Cancellous bone
6.	Cortical bone
7.	Dentin and cementum
8.	Enamel.

Scattering: is the change in direction of a photon with or without a loss of energy.

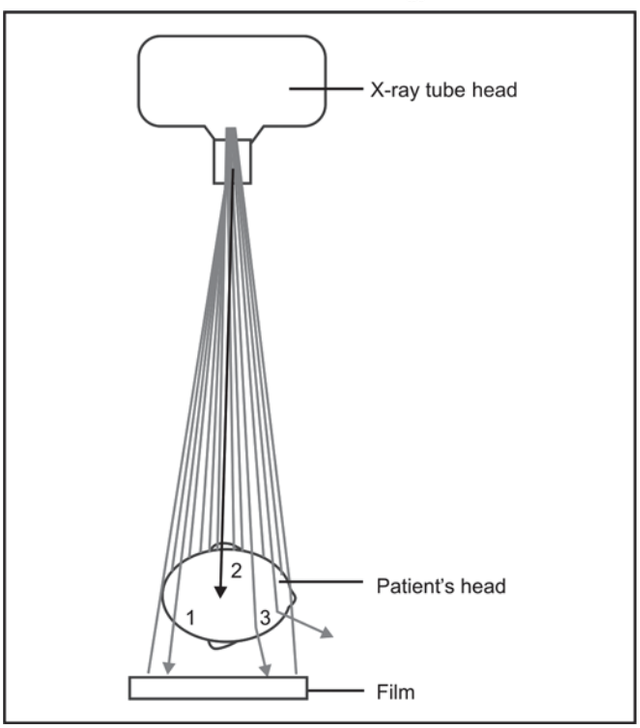


Fig. 3.6: Three types of radiation interactions with the patient, may occur. 1. The X-ray photon may pass through the patient without interaction and reach the film. 2. Photon may be totally absorbed. 3. The photon may be scattered onto the film or away from the film

In the case of the diagnostic X-ray beam there are three mechanisms by which these processes take place:

1. Coherent scattering.
2. Photoelectric effect.
3. Compton scattering.

Effect of Interaction of X-rays with Matter (Fig. 3.7)

1. Coherent or Elastic Scattering is a process by which radiation is deflected without losing energy (Fig. 3.8).
   - X-rays when passing close to an atom causes the "bound electrons" to vibrate momentarily at a frequency equal to that of the incident photon.
   - The incident photon then ceases to exist.
   - The vibration causes the electron to radiate energy in the form of another X-ray photon of the same frequency and energy as that in the incident beam.
   - Usually the secondary photon emitted is at an angle to the path of the incidental X-ray.

In short, the direction of the incident X-ray has been altered, usually low energy photons undergo coherent scattering.

At energy levels employed in diagnostic radiology, the effect of coherent scattering is negligible in production of fog. This property is used to investigate internal molecular structure of materials, by the method of X-ray diffraction, called X-ray crystallography.

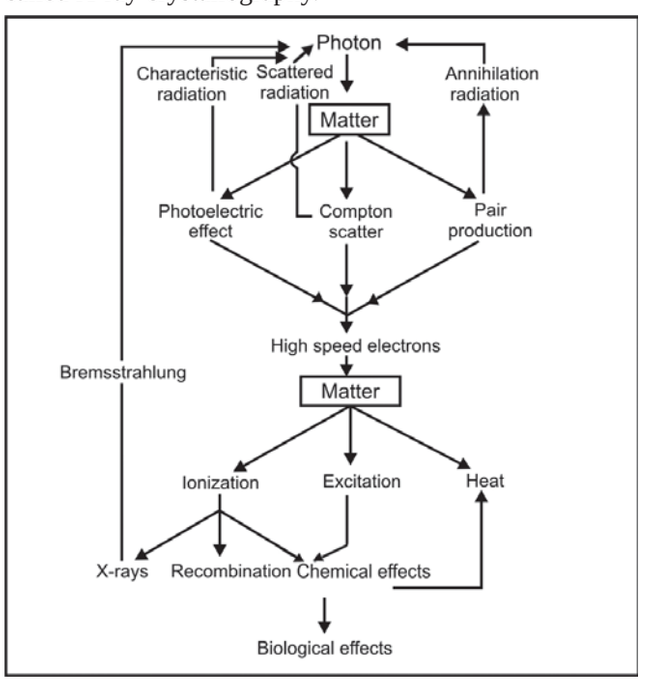


Fig. 3.7: The effect of interaction of X-rays with matter

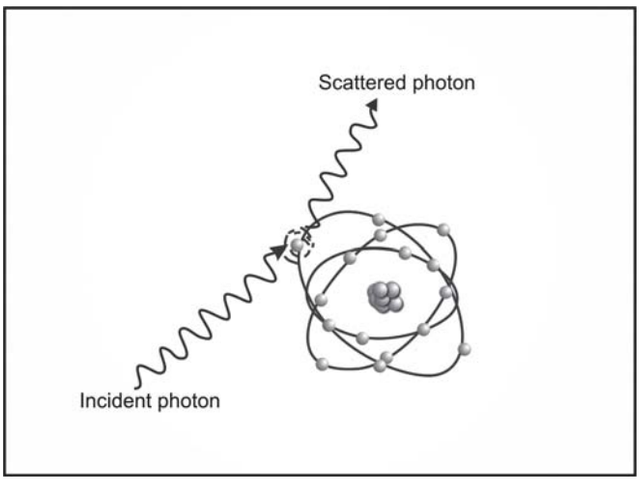


Fig. 3.8: Coherent scattering resulting from the interaction of low-energy incident photon with outer electron, causing it to vibrate momentarily. After this interaction, scattered photon of the same energy is emitted at a different angle to the path of incident photon

2. Photoelectric Effect is a process of interaction of the incident photon and the bound electron leading to emission of characteristic radiation (Fig. 3.9).
   - It occurs when an incident photon collides with a bound electron in the atom of the absorbing medium.
   - The incident photon ceases to exist and its energy helps to eject a bound electron from its shell to become a recoil electron or a photo electron.
   - The kinetic energy imparted to the recoil electron is equal to the energy of the incident photon minus that required to overcome the electron binding energy.
   - The ejection of the electron will ionize the atom.
   - The orbital vacancy caused by the electron reshuffle and the neutrality is obtained by attracting an electron from outside.
   - During this rearrangement characteristic radiation is emitted.

   About 30 percent of photons absorbed from a dental X-ray beam are absorbed by the photoelectric process. In diagnostic radiography the characteristic radiation generated is of no significance as the X-ray photons which are absorbed by the patient are of such low energy, that they are absorbed within the patient. This is good for the dentist as there is no scattered radiation but bad for the patient because of increased radiation absorption. (when contrast agents-like iodine or barium are used, they will emit characteristic radiation, energetic enough to exit the patient and fog the film).

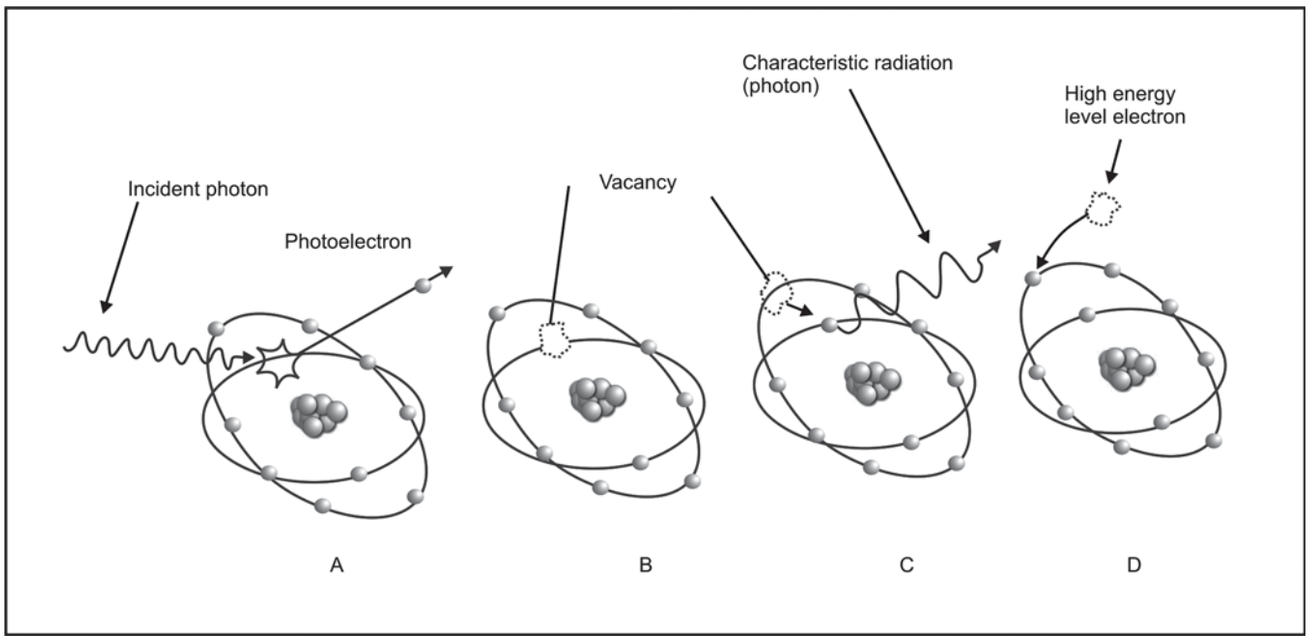


Fig. 3.9: A. Photoelectric absorption occurs when the incident photon gives up all its energy to inner electron, ejected from atom as photoelectron. B. An electron vacancy in the inner orbit results in ionization of the atom. C. An electron from a higher energy level fills the vacancy and emits characteristic radiation. D. All orbits are subsequently filled, completing energy exchange

3. Compton Scattering or Inelastic Scattering is an interaction of photons with free or loosely bound outer shell electrons (Fig. 3.10).
   - The photon gives some of its energy to the electron and it, itself continues in a new direction (scattered or modified compton attenuation), but with reduced energy and hence with increased wavelength.
   - The ejected outer shell electron is called compton or recoil electron.
   - The angle through which the photon is scattered depends upon the energy lost by the photon.
   - If scattered through a small angle, very small amount of energy is lost to the outer electron.
   - In case of a head on collision, the photon is turned back along its track and maximum energy is transferred to the recoil electron (unmodified compton attenuation), and all the energy is lost.
   - The recoil electrons undergo further ionizing interactions within the tissues, and gradually lose energy along their tracts by causing secondary radiations and consequent biological damage.
   - The scattered photon may undergo further compton interactions and/or photoelectric effects and/or escape from the tissue. It is the latter which forms scattered radiation of concern in the clinical environment.

The importance of photoelectric and compton absorption in diagnostic radiography relates to the difference in the way photons are absorbed in various anatomic structures.

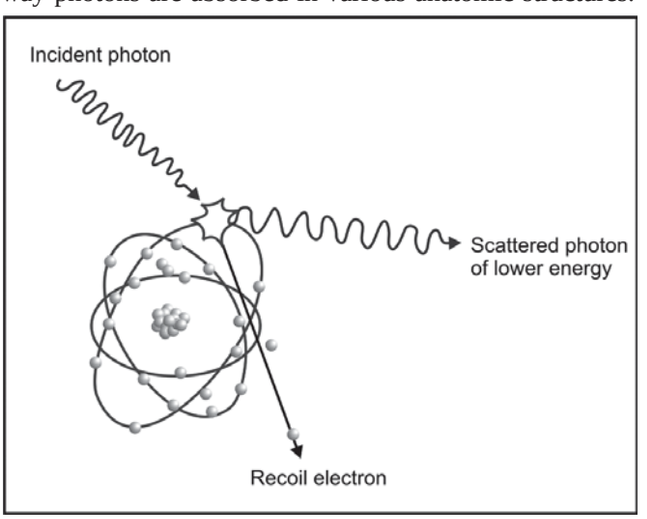


Fig. 3.10: Compton absorption occurs when the incident photon interacts with the outer electron, resulting in a scattered photon of lower energy than the incident photon and a recoil electron ejected from target atom

The probability of both photoelectric and compton interactions of photons with matter is more probable in hard tissues than in less mineralized soft tissues, there are more photons in the beam exiting the patient after traversing soft tissue, than through hard tissue. As a consequence a radiograph readily distinguishes between many tissues including enamel, dentine, bone and soft tissue.

Pair production: When a photon having excess energy (equal to or more than 1.02 Mev) passes close to the nucleus of an atom, the photon may completely disappear and in its place positive and negative electrons appear. Thus, the mass is produced from energy but the total charge remains unchanged.

The positive electron is very unstable and combines with another negative electron, they annihilate, changing back into energy equivalent to their masses, producing *Annihilation Radiation*.

16. Due to their energy X-rays can release photoelectrons from the metals, when allowed to fall on them.
17. Heating effect: The production of heat is one of the initial results of the slowing down of the primary electrons, it also arises as an end product of the chemical reactions induced by radiations. This change in temperature is very small and can only be detected by very sensitive instruments.
18. Fluorescence: When X-rays fall upon certain materials, visible light is emitted called fluorescence, and it was this very property which led to the discovery of X-rays.

    There are different ways in which materials may emit light (luminescence) when X-rays are incident upon them.

    a. Phosphorescent materials: These materials continue to emit light for a period of time after the X-ray absorption has taken place. This is called 'after glow' and it is used in the advertisement hoardings and lightings.
    b. Fluorescent materials: Here the emission of light is instantaneous, quickly completed following X-ray irradiation. This property is used in Intensifying screens and Mass Miniature Radiography (photo fluorography).

       Mechanism of fluorescence: Fluoroscent materials are crystalline and have electron levels similar to that of an isolated atom. The emission characteristic depends upon the energy level from which the electron is removed. Electron from low energy level produces visible light and those from high energy level produces X-rays. In fluorescence the emphasis is on the outer electron level since it is the emission of visible light which constitutes the process.

The pattern of energy levels in solids; the inner levels (K, L, etc.) of each of the atoms comprising the solid are exactly the same as that for the single atom and the presence of nearby atoms of the solid have no effect on these levels. The inner levels are completely filled with electrons. For the outer levels (O, P, etc.), many of which are empty, thus the situation is different. Instead of each electron being restricted to a definite energy value, the presence of the other atoms makes it possible for the electron to have any energy within a small but definite range. These now overlap to form a wide band of possible electron energies (Fig. 3.11).

The CB is represented by level O, the energy level at which the electron can leave the material and level E_1, the band formed from some of the broadened out energy levels. This is called conduction band, since any electron which happens to be in this band can move freely and therefore exhibit the phenomenon of electrical conduction. In fluorescent material this band is empty, therefore the material is also an insulator.

Forbidden zone: Extends from level E_1 to level E_2, this corresponds to the region between energy levels of an atom. No energy level electron can exist in this region.

Filled band: Extends from level E_2 to level E_3, this is a continuous band of energy levels, all of which are filled, with no place for any more

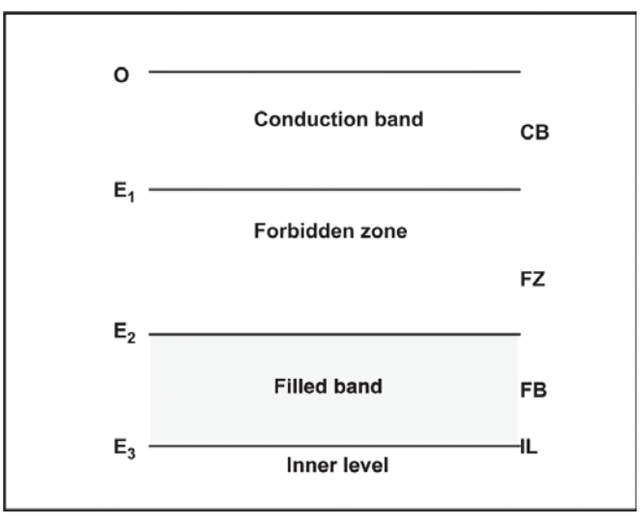


Fig. 3.11: The electron band structure of a perfect and pure, crystal of an insulating material

electrons. Electrons can be removed from this band, to leave behind holes.

Inner level: This lies below level E_3, these are unmodified discrete single inner energy levels which are of no importance in the discussion on fluorescence.

Electron trap: is the presence of impurities and faults resulting in an extra energy level in the FZ. The electron present is said to be trapped and these localized energy levels are called electron traps.

The property of fluorescence can now be described:

If there is an electron trap (ET) and a hole (H) in the filled band then these two may combine leading to the emission of a single photon of visible light. The spectrum of light visible is a result of many such events.

1. X-ray energy is absorbed and a secondary electron is produced.
2. The secondary electron creates many holes in the FB and lifts electrons to the CB.
3. Electrons already in the traps combine with the created holes to emit visible fluorescent light photons.
4. Sometimes electrons fall directly from the CB to fill the holes and emit fluorescent photons.
5. The vacated traps are refilled by electrons from the CB.
6. Many X-ray photons are absorbed and as a result many visible light photons are emitted and their spectrum is a continuous one.

Thermoluminescent materials: These emit visible radiations during or after irradiation of X-rays but only if heated to a few 100 degrees centigrade. This is used in comparative dosimetry and TLD badges.

19. Ionization: This is a process of converting atoms into ions (Fig. 2.2).
    a. X-rays can ionize gases and thus increase the electroconductivity of a gas through which it passes. Ionized air is accepted as the basis for X-ray measurement and for the definition of unit of X-ray quantity (Roentgen).

       Various devices that work on the principle of ionization are:

       i. Ionization chamber.
       ii. Thimble chamber.
       iii. Condenser chamber.
       iv. Geiger Muller counter.
       v. Scintillation counter.

    b. Ionization also takes place whenever an X-ray photon strikes matter producing secondary radiation, and the effects of X-rays is largely due to this process.
    c. X-ray radiation by virtue of its intrinsic ionizing potential can activate and dissociate silver ions in silver halide. This property is used in diagnostic radiology.

Chemical Properties

The outer electrons of the atoms play an important role in chemical combinations and therefore any disturbance in the outer electron configuration of an atom brings about a chemical change.

1. X-rays induce color changes of several substances or their solutions.
   i. Methylene blue gets bleached.
   ii. Sodium platinocyanide which is apple green turns to darker shades, then light brown and finally dark brown.

   These color changes are used to detect cases of forgery and dose measurement.
2. X-rays bring about chemical changes in solutions which are otherwise completely stable. This is because X-rays produce the highly active radical 'OH' in water, which reacts with the solutes.
   i. This brings about molecular changes in biological molecules.
   ii. Organic compounds get oxidized to carbon dioxide with release of hydrogen when exposed to radiation, because water in organic substances undergoes oxidation and reduction reactions when irradiated.
   iii. X-rays can cause oxidation of ferrous sulphate to ferric sulphate and this is used as a method of measuring X-ray dosage (Frickle Dosimeter).
3. X-rays can cause destruction of the fermenting power of enzymes, which are vital substances for the metabolism of cells of all living materials.

Biological Properties

When X-rays are incident on an atom, one of the reaction it produces is 'excitation.' *This state of 'excitation' in biological materials enable it to take part in a chemical process into which in the normal state it would not enter*. This is an important cause of biological damage produced by radiation.

i. This property of excitation is used in the treatment of malignant lesions.
ii. X-rays also have a germicidal or bactericidal effect and are used for sterilization and preservation of food.

The biological effects of X-rays may be classified into two types:

i. *Somatic effect*: This ranges from a simple sun burn to severe dermatitis, to changes in the blood supply and/or malignancy. The effect is cumulative and depends upon the type of tissues and intensity of the radiation.
ii. *Genetic effect*: This effect is due to radiation induced mutation of genes and chromosomes. These effects are usually seen in the off-springs of the irradiated parents.

The fetus is more sensitive to radiation in the early stage of development.

Physiochemical Properties

The photographic effect: photographic paper or film when exposed to X-ray radiation and then developed will be found blackened. The irradiation effects the silver salts in the emulsion, so that after the chemical process called developing, the radiograph metallic silver is released and the film or paper appears blackened.

This blackening is known as 'film density' and the degree of blackening depends upon:

i. Amount of radiation.
ii. Quality of radiation.
iii. Characteristic of a film.
iv. Concentration and age of developing solution.
v. Length of developing time.
vi. Use of intensifying screens.

The difference between the degree of density is known as 'film contrast.'

Table 3.2: Diagnostic Properties of X-rays

1. X-rays travel in a straight line.
2. **Penetration:** X-rays can penetrate liquids, solids and gases. The composition of the substance determines whether the X-rays penetrates or are absorbed.
3. **Absorption:** X-rays are absorbed by matter, the absorption depends on the atomic structure of the matter and the wavelength of the X-ray.
4. **Ionizing capability:** X-rays interact with materials they penetrate and cause ionization.
5. **Fluorescence:** X-rays can cause substances to fluorescence or emit light radiation in longer wavelengths. (e.g. visible light or ultra-violet light).
6. **Effect on films:** X-rays can produce an image on a photographic film.
7. **Effect on living tissues:** X-rays cause biological changes in living cells.

USES OF X-RAYS

1. Radiology:
   i. Diagnostic use in dentistry and medicine, helps to diagnose various pathological lesions.
   ii. Medicolegal cases.
2. Radiotherapy: X-rays are used to destroy malignant tumors and to cure skin diseases. The treatment may be curative or palliative. Curative treatment may be in combination with surgical treatment.
3. Industry:
   i. Used to detect defect in radio valves, tennis balls, tyres.
   ii. Used to detect presence of pearls in oysters.
   iii. Used to test the uniformity of insulating material.
   iv. Used to test the quality of oil paintings.
4. Engineering:
   i. For examination of gross structures.
   ii. Used to detect cracks in structures and blow holes in metals.
   iii. To test quality of welding, moulds and metal castings.
   iv. To detect cracks in the body of airplanes, motor cars and vans.
5. Spectroscopy: Identification of elements and their atomic numbers and structures.
6. Photochemistry: Ionization of chemicals producing oxidation reduction, etc.
7. Radiobiology: Alteration of cells and tissues for experimental purposes.
8. Crystallography: Analysis of molecular structures.
9. Sterilization: Preservation of food.
10. Detective department:
    i. To detect smuggling of precious metals and other contrabrand goods like opium in sealed parcels and leather pouches.
    ii. Used in mints to check people as they enter and leave.
    iii. Used for checking personal while entering and leaving restricted areas for security purposes.

BIBLIOGRAPHY

1. Curry TS, Dowdy JE, Murry RC. Christensen's Introduction to the Physics of Diagnostic Radiology, (3rd edn), Philadelphia, Lea and Febiger, 1984.
2. John HE, Cunningham JR. The Physics of Radiology, (4th ed), Springfield, Charles C Thomas, Publisher, 1985.
3. Merdith WJ, Massey JB. Fundamental Physics of Radiology, Second edition, Bristol: John Wright and Sons. 1972.

4

Production of X-Rays

X-rays are produced by the sudden deceleration or stoppage of a rapidly moving stream of electrons at a metal target in a high vacuum tube. The X-ray tube is an important part of any X-ray machine. Dental X-ray machines can be used to expose intraoral as well as extra oral films. Some machines are used only for intraoral films whereas others are for extraoral films. Now, digital radiography units are also available.

The dental X-ray machine is made up of three parts or components: (Fig. 4.1)

i. Control Panel
ii. Extension Arm
iii. Tube Head.

Control Panel of the dental X-ray machine contains (Fig. 4.2)

a. An on and off switch and an indicator light
b. An exposure button and indicator light
c. Control devices (time, kilo voltage, milli amperage selectors) to regulate the X-ray beam.

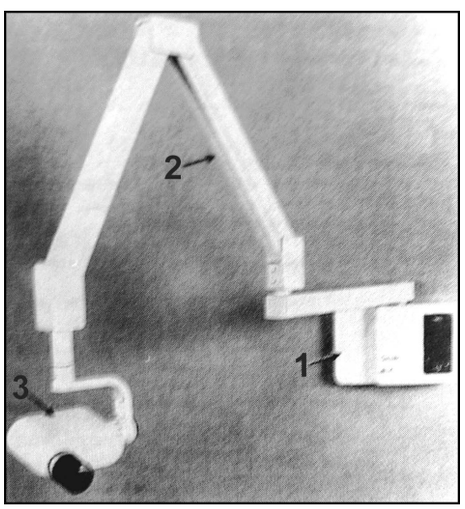


Fig. 4.1: Three component parts of the dental X-ray machine (1) Control Panel; (2) Extension Arm; (3) Tube Head

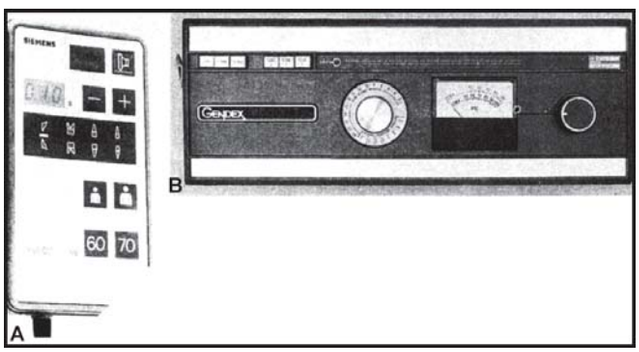


Fig. 4.2: A. The Helodent MD Control Panel, B. The Gendex – 1000 Control Panel

The control panel is plugged into an electrical outlet.

Extension Arm: The extension arm suspends the X-ray tube head and houses the electrical wires that extend from the control panel to the tube head. The extension arm also allows the movement and positioning of the Tube Head.

Tube Head: It is a tightly sealed, heavy metal housing that contains the X-ray tube that produces dental X-rays. The component parts of the X-ray tube include the following: (Figs 4.3 and 4.4).

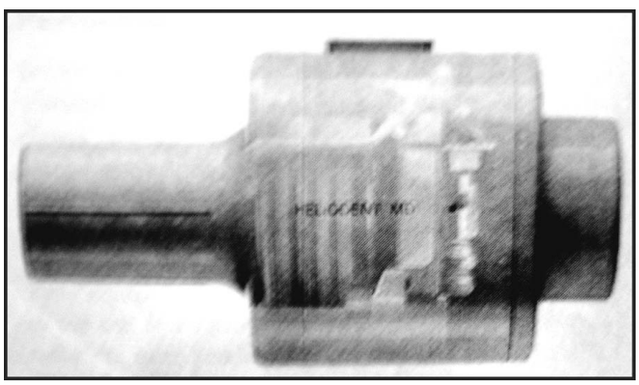


Fig. 4.3: The Tube Head which contains the X-ray Tube

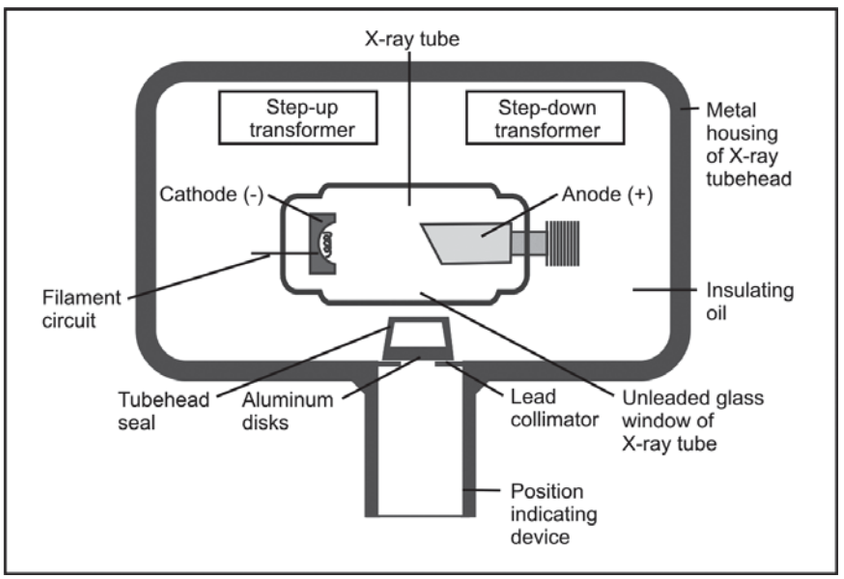


Fig. 4.4: Schematic diagram of the dental X-ray tube head

i. *Metal Housing*: This is the metal body of the tube head that surrounds the X-ray tube and transformer and is filled with oil, it protects the X-ray tube and grounds the high voltage component.

ii. *Insulating Oil*: It is that which surrounds the X-ray tube and transformer inside the tube head, it prevents over heating by absorbing the heat created by the production of X-rays.

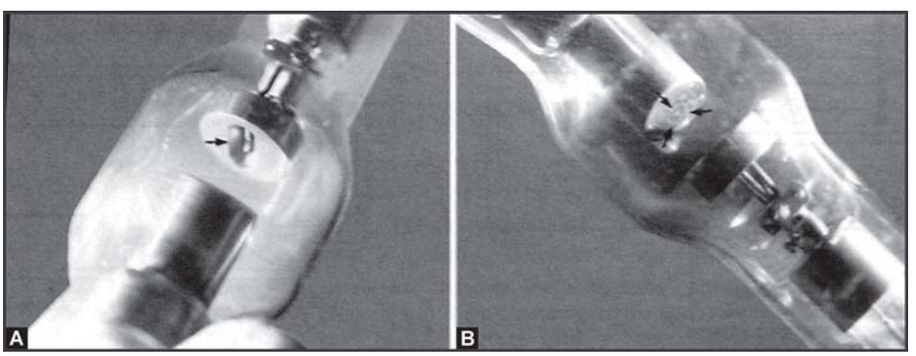
iii. *Tube Head Seal*: Aluminum or leaded glass of the tube head that permits the exit of X-rays from the tube head, it seals the oil in the tube head and acts as a filter to the X-ray beam.

iv. *X-ray Tube* (Figs 4.5A and B): It is the main X-ray generating system.

v. *Aluminum Disks* (Fig. 4.6): The sheets of 0.5 mm thick aluminum is placed in the path of the X-ray beam. They filter out the non penetrating, longer wave length X-rays, resulting in a higher energy and more penetrating useful beam, which is less harmful to the patient (decreased skin dose). In the dental X-ray tube head there are two types of filtration:

a. Inherent filtration.
b. Added filtration.

a. Inherent filtration takes place when the primary beam passes through the glass window of the X-ray tube, the insulating oil and the tube head seal. In the dental X-ray machines the inherent filtration is approximately equivalent to 0.5 to 1 mm of aluminum.



Figs 4.5A and B: A. Focusing cup containing a filament in the cathode of the tube from an X-ray machine. **B.** The focal spot area on the target of the tube. The size and the shape of the focal area approximate those of the focussing cup

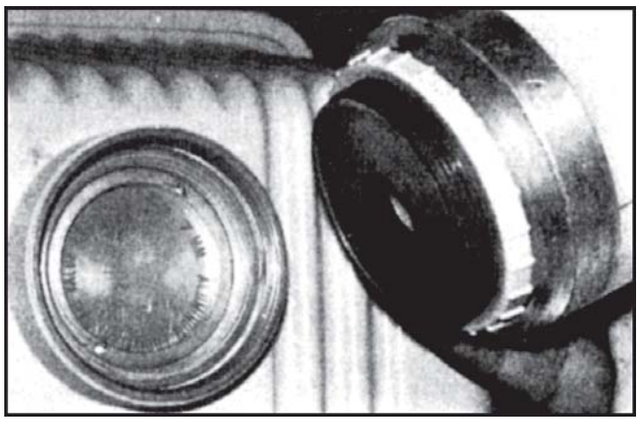


Fig. 4.6: Aluminum disk in the X-ray tube head

This amount of filtration usually does not meet the standards regulated by the state and federal law (in USA) and therefore added filtration is required.

b. Added filtration refers to the placement of aluminum disks in the path of the X-ray beam between the collimator and the tube head seal in the dental X-ray tube head. Aluminum disks may be added in 0.5 mm increments.

Total filtration (inherent + added filtration) is regulated by the state and federal law (in USA). Dental machines operating:

- At or below 70 kVp. require a minimum total filtration of 1.5 mm of aluminum thickness.
- Above 70 kvp. require a minimum total filtration of 2.5 mm of aluminum thickness.

vi. *Lead collimator* (Fig. 4.7): It is a lead plate with a central hole that fits directly over the opening of the metal housing where the X-rays exit.

Collimation is used to restrict the size and shape of the X-ray beam and thus reduce exposure to the patient.

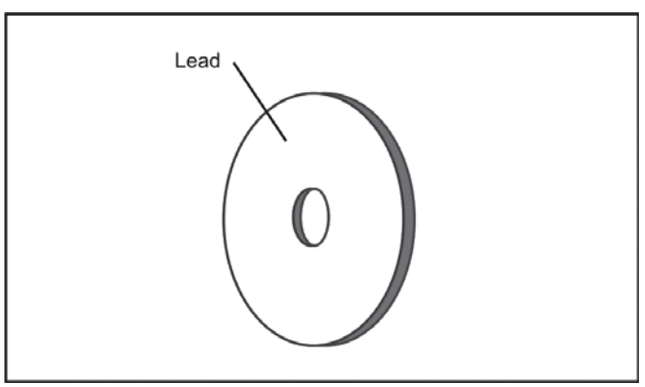


Fig. 4.7: Schematic drawing of the lead collimator or lead plate, with a central opening. This restricts the size and shape of the X-ray beam

Collimators are of two types: a. Fixed. b. Adjustable.

In the dental X-ray machine usually the fixed collimators are used, they may either have a round or rectangular opening.

A rectangular collimator restricts the size of the X-ray beam to an area slightly larger than a size of 2 intraoral (normal adult intraoral periapical films) and thus significantly reduces the patient exposure.

A circular collimator produces a cone shaped beam that is 2.75 inches in diameter and is considerably larger than the size of two intraoral periapical films, and thus leads to an increased skin dose to the patient.

vii. *Position Indicating Device (PID)* (Fig. 4.8): or open ended lead cylinder, that extends from the opening of the metal housing of the tube head also called the "cone".

The PID appears as an extension of the tube head and it aims and shapes the X-ray beam. There are three types of PID's:

i. conical
ii. rectangular
iii. round.

The conical PID appears as a closed, pointed plastic cone and when X-rays exit they penetrate the plastic and produce scattered radiation.

Now a days lead lined rectangular or round PID's are preferred as they do not produce scattered radiation.

Both rectangular and round PID's are available in two lengths:

i. short (8 inches)
ii. long (16 inches).

The long PID is preferred because less divergence of X-ray beam occurs. The rectangular type is most effective in reducing patient exposure.

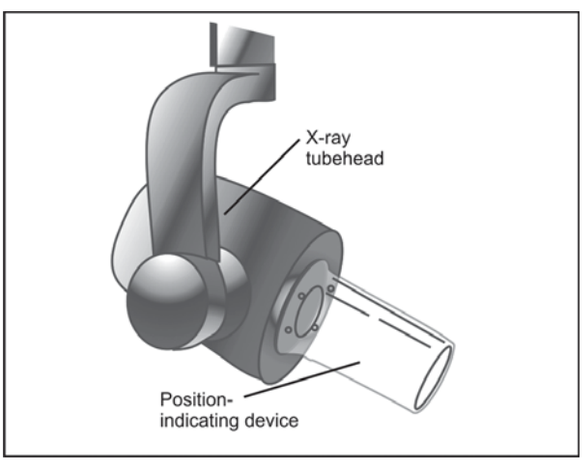


Fig. 4.8: The Position Indicating Device (PID) or cone

The X-ray Tube (Fig. 4.9): It is the heart of the X-ray generating system. This consists of a glass vacuum tube from which all of the air has been removed. The X-ray tube used in dentistry measures approximately several inches long by one inch in diameter. The component parts of the X-ray tube consist of:

a. A leaded glass housing
b. A negative cathode
c. A positive anode.

a. *A leaded glass housing*: It is a leaded glass vacuum tube that prevents X-rays from escaping in all directions (radiation leakage). One central area of the leaded glass tube has a "window" that permits the X-ray beam to exit the tube and directs the X-ray beam towards the aluminum disk, lead collimator and PID. This is also used for earthing.

b. *A negative cathode*: It is principally composed of two parts:
   i. filament.
   ii. focussing cup.
   - The filament is the source of electrons in the tube, it is made up of a coil of tungsten wire (atomic number 74), approximately 0.2 cm in diameter and 1cm or less in length. It is mounted on two strong stiff wires, that support it and carry the electric current. These two mounted wires lead through the glass envelope to serve as a connection to the low and high voltage electrical source.

     The filament is heated to incandescence through a range of temperatures by varying voltage (10V), across the filament from a step down transformer in a low voltage circuit. The hot filament emits electrons that are separated from the outer orbits of tungsten atoms at a rate proportional to its temperature by a process called *"Thermionic emission"* The electrons lost by the filament form a cloud or space charge around the filament. (These are replaced from the negative side from the high voltage circuit which is connected to one of the filament mounting wire.)

     A milli ampere control provides for fine adjustment of voltage across the filament and in turn the flow of heating current through it. The milli ampere control, thereby controls the quantity of electrons the filament emits, which in turn controls tube current.

   - The focussing cup is a negatively charged concave reflector cup of molybdenum and houses the filament. The focussing cup electrostatically focuses the electrons emitted by the incadescent filament into a narrow beam, (thereby restricting the size of the electron cloud) directed at a small rectangular area in the anode—the focal spot.

     The electrons are caused to move in this direction because of a strong electric field interposed between the cathode and the anode, by a high negative charge placed on the cathode which repels the electrons in the electron cloud towards the anode which has a high positive charge. This is achieved by applying a high voltage circuit between the anode and the cathode.

     To facilitate the movement of the electron cloud, the X-ray tube is evacuated as completely as possible to prelude collision of moving electrons with gas molecules, which could significantly reduce their speed. It also prevents oxidation or 'burn out' of the filament.

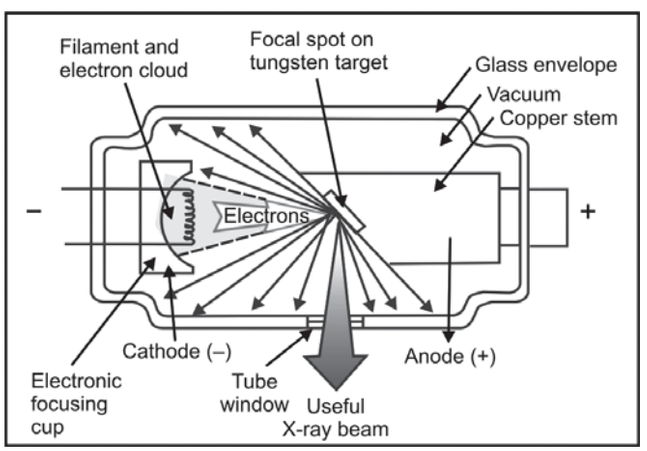


Fig. 4.9: X-ray tube with the major components labeled

c. *A positive anode or the positive electrode*: It consists of a wafer thin tungsten plate (target) embedded in a solid copper stem. The purpose of the target is to convert the kinetic energy of the electrons generated from the filament into X-ray photons.

Tungsten is usually selected as the target material because it represents an effective compromise between the features of an ideal target material, namely:

i. *High atomic number*: This is desired for more efficient production of X-rays. High atomic number indicates high charge on the nucleus (more protons) and high binding energy of orbital electrons. This high charge on the nucleus causes greater deceleration of bombarding electrons which approach the nucleus and of incoming electrons that collide with the inner shell electrons producing higher energy radiation. In

brief, high atomic number gives rise to increased inter action between electrons and atoms, thereby increasing X-ray photons.

ii. *High melting point*: 3380°C, so that even if the temperature rises the target will not melt.

iii. *Low vapor pressure*: So that at high temperatures, it does not evaporate.

iv. *High specific heat* (conduction of heat) to facilitate dissipation of heat, but tungsten is a poor conductor of heat.

Therefore, the tungsten target is embedded in a copper block which is a good thermal conductor.

The methods of heat dissipation are:

i. Conduction: through the copper stem.
ii. Convection: through the oil surrounding the tube.
iii. Radiation: through the radiator device attached to the copper stem.
iv. Rotating anode.

There are two types of anodes:

1. Stationary or Fixed anode.
2. Rotating anode. (Fig. 4.10) This type of anode is used to help dissipate heat from a small focal spot. The tungsten target is in the form of a small beveled disk that rotates when the tube is in operation. As a result electrons strike successive areas of the target as it rotates. This widens the focal spot to an amount corresponding to the circumference of the beveled disk and distributes heat over an expanded area. As a result of using rapidly rotating beveled disk target, fractional millimeter focal spots can be used with currents up to 100 mA to 500 mA, that is ten to fifty times that of stationary anode.

The target and the rotor (armature) of the motor are located within the X-ray tube where as the coils which drive the rotor at about 3000 rpm are situated outside the tube. Such rotating anodes are not used in conventional dental X-ray machines, but may be used in cephalometric or extra oral X-ray machines.

Target size: The radiographic image quality is dependent upon the geometry of the target. Sharpness of the radiographic image increases as the size of the radiographic source (that is focal spot) decreases.

The focal spot is the area on the target onto which the focussing cup directs the electrons from the filament.

As the focal spot becomes smaller, heat generated per unit target area becomes greater. Thus in order to derive benefit from a small focal spot and yet to effectively distribute the bombarding electrons over a greater surface of a large target, the target is placed at an angle to the electron beam. (The effective focal spot will be smaller than the actual size of the focal spot that is projected, perpendicular to the target).

In practice the target is inclined at an angle of 20° to the central ray of electrons. This causes the effective focal spot to be 1 mm × 1 mm, in contrast to 1 mm × 3 mm of the actual focal spot size. This results in a smaller source of X-rays and sharper image with a larger actual focal spot for effective heat dissipation. This is known as *"Line focus principle"* and the *twenty degree angle* is called as *"the angle of truncation"* (Fig. 4.11).

[*The effective focal spot size may be decreased and the sharpness of the resulting radiograph increased, by continuing to reduce the angle of the anode with*

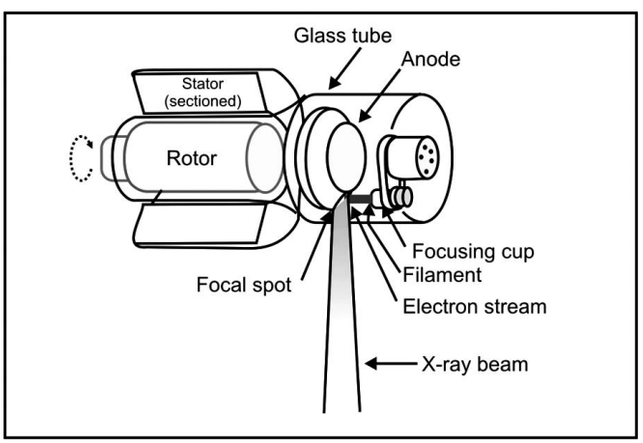


Fig. 4.10: X-ray tube with a rotating anode, which allows heat at the focal spot to spread out across a large surface area

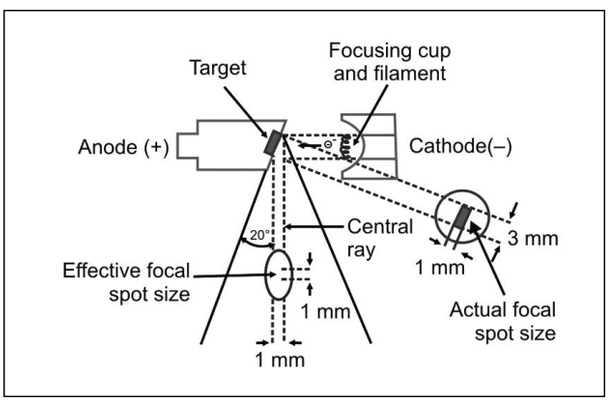


Fig. 4.11: The angle of the target to the central ray of the X-ray beam has a strong influence on the apparent size of the focal spot. The projected effective focal spot is much smaller than the actual focal spot size

respect to the central ray. In practise however, this is limited by ***'the heel effect'****. Fig. 4.12. The intensity of the beam is not uniform across the exposure field, because the distance from the anode to a point on the film away from the perpendicular is greater than the center of the exposure field. (Inverse Square Law). This nonuniform distribution of photons contributes to the heel effect and is accentuated as the angle of the target is reduced.* ***In dentistry as the size of the film is relatively small the heel effect is not seen.***]

Electricity and Electric Currents

Electricity: It is the energy that is used to produce X-rays.
Electrical energy: It is the flow of electrons through a conductor and is also called 'Electric Current'.
Electric current may be:

i. Direct current (DC): When electrons flow in one direction only.
ii. Alternating current (AC): Describes a current in which the electrons flow in two opposite directions.

Rectification: It is the conversion of alternating current to direct current.

The dental X-ray tube acts as a self rectifier, in that it changes AC to DC while producing X-rays.

During the first phase, the cathode is negatively charged and the anode is positively charged, the electrons flow from the cathode and hit the anode and X-rays are produced. But when the current changes direction, the cathode becomes positively charged and therefore the electrons present at the anode will travel backwards and hit the filament, this occurs in general X-ray machines where very high voltage is used. In the dental X-ray machine, however, the amount of heat produced at the anode does not give rise to excessive electrons as a result, when the current changes its direction, there are no electrons at the anode to travel back to the cathode, this half of the cycle is called inverse voltage or reverse bias, hence the dental X-ray tube is called *self rectifying or half wave rectifying.*

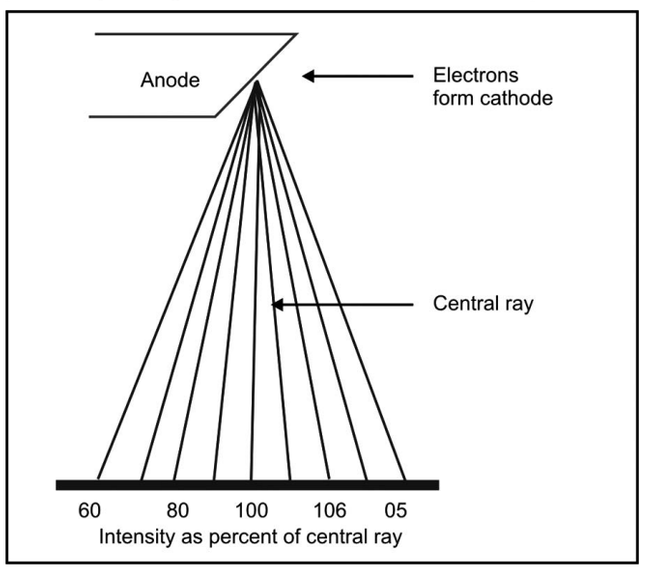


Fig. 4.12: Heel effect is shown as relatively low intensity of the X-ray beam on anode side of the central ray caused by self absoption of photons in the target

The newer consistent potential X-ray machines produce a homogenous beam of consistent wavelengths during exposure and this helps to reduce patient exposure to radiation by 20 percent.

Amperage: It is the measurement of the number of electrons moving through a conductor.

Current is measured in Amperes (A) or Milli amperes (mA.)

Voltage: It is the measurement of electric force that causes electron to move from a negative pole to a positive one. It is measured in Volts (V) or kilovolts (kV).

If the milli amperes (mA) increases, the number of electrons passing through the cathode filament increases.

Circuit: It is a path of electrical current.

In the production of X-ray, two circuits are used (Fig. 4.13):

i. *Filament circuit*: It is low voltage (3-5volts) and regulates the flow of electrical current to the filament of the X-ray tube. It is controlled by the mA setting in the Control Panel.
ii. *High voltage circuit*: It uses 65,000 to 1,00,000 volts, providing a high voltage required to accelerate electrons

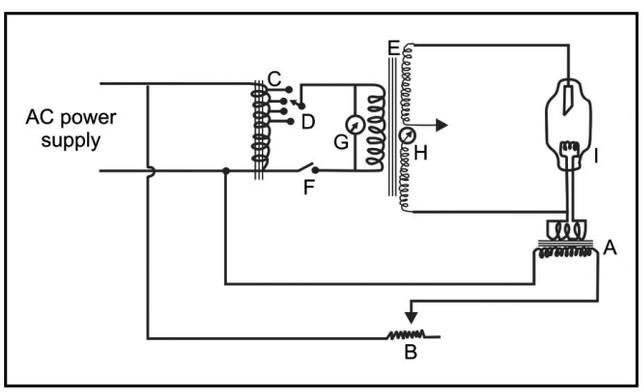


Fig. 4.13: Dental X-ray machine circuit, with the major components labeled.
A. Filament Step-Down Transformer; B. Filament Current Control (mA switch); C. Autotransformer; D. kVp Selector Dial (switch); E. High Voltage Transformer; F. X-ray Timer (switch); G. Tube Voltage Indicator (Volt Meter); H. Tube Current Indicator (Ammeter); I. X-ray Tube

to generate X-rays in the X-ray tube. It is controlled by the kVp setting in the control panel.

Transformer (Fig. 4.14): It is a device that is used to either increase or decrease the voltage in an electrical circuit.

It alters the voltage of the incoming electrical current and then routes the electrical energy to the X-ray tube.

In the production of X-rays three transformers are used:

i. *Step Down Transformer*: It is used to decrease the voltage from the incoming 110-220 line voltage to 3-4V as required for the filament circuit. (This transformer has more coils in the primary coil than in the secondary coil).
ii. *Step Up Transformer*: It is used to increase the voltage from the incoming 110-220 line voltage to 65,000-1,00,000 volts as required by the high voltage circuit.
iii. *Auto Transformer*: This serves as a voltage compensator that corrects the minor fluctuations in the current.

Timer: A timing control device, used to control X-ray exposure time. It is included in the primary high voltage supply. The timer completes the circuit with the high voltage transformer thereby controlling the time that the high voltage is applied to the tube and thus the time during which the tube current flows and X-rays are produced.

The timing circuit first sends a current through the filament to get it to the proper operating temperature. Once the filament is heated, a time delay switch applies power to the high voltage circuit.

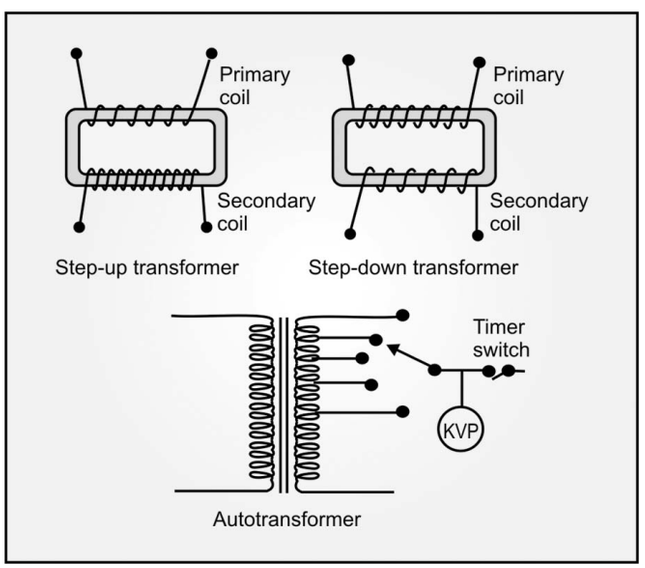


Fig. 4.14: Three different transformers used in the production of X-rays

Tube rating and duty cycle: Each tube has a rating specification that describes the operating limits of the tube. These specifications are on the tube rating charts that describe in a graph like representation the maximum safe intervals (seconds) the tube may be energized at a given range of voltage (kVp) and the tube current (mA) values.

The Duty Cycle refers to how frequently successive exposures can be made. The heat build up at the anode is calculated as Heat Unit (HU) = kVp x mA x Sec. (watt.sec).

Production of X-rays (Fig. 4.15)

1. Electricity from the wall outlet supplies the power to generate X-rays. When the X-ray machine is turned on, the electric current enters the control panel, via the plugged in cord and from there to the tube head via electrical wires in the extension arm.
2. The current is directed to the filament circuit through the step down transformer, which reduces the 110-220 voltage to 3-5 volts.
3. The filament circuit uses the 3-5 volts to heat the tungsten filament. Thermionic emission occurs, which results in the release of electrons from the tungsten filament, which form an *'electron cloud'*. This cloud remains around the filament till the high voltage circuit is activated.

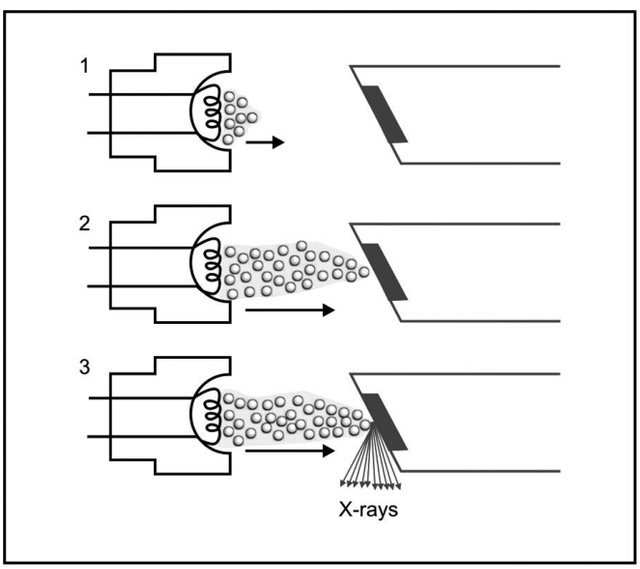


Fig. 4.15: The production of dental X-rays occurs in the X-ray tube. **1.** When the filament circuit is activated, the filament heats up and thermionic emission occurs. **2.** When the exposure button is activated, the electrons are accelerated from the cathode to the anode. **3.** The electrons strike the tungsten target, and their kinetic energy is converted to X-rays and heat

4. When the exposure button is pushed the high voltage circuit is activated. The electron cloud produced at the cathode is accelerated across the X-ray tube to the anode. The molybdenum cup of the cathode directs the electrons to the tungsten target in the anode.
5. The electrons travel from the cathode to the anode. When the electrons strike the tungsten target, their energy motion (kinetic energy) is converted to X-ray energy and heat. Less than 1 percent of the energy is converted to X-rays, the remaining 99 percent is lost as heat.
6. The heat produced is carried away by the copper stem and absorbed by the insulating oil in the tube head. The X-rays produced are emitted from the Target in all directions. However, the leaded glass housing prevents the X-rays from escaping from the X-ray tube in any direction. Only a small number of X-rays are able to exit from the X-ray tube via the unleaded glass window portion of the tube.
7. The X-rays travel through the unleaded glass window, the tube head seal, the aluminum disks, which filter the long wave X-rays from the beam.
8. The size and shape of the X-ray beam is controlled by the lead collimator. The X-ray beam then travels down the lead lined PID and exits the tube head at the opening of the PID.

Types of X-rays produced: The X-rays produced in the X-ray tube vary in energy and wave length, depending on how the electrons interacted with the tungsten atoms in the anode. The kinetic energy of the electrons is converted to X-ray photons via one of the following mechanism:

a. General (Bremsstrahlung Radiation or Braking Radiation) Radiation (Fig. 4.16). The term refers to the sudden "braking" of high speed electrons when they hit the tungsten target in the anode. 70 percent of the X-rays are produced in this manner.

   If the electron hits the nucleus of the tungsten atom all its kinetic energy is converted into "High Energy X-Ray Photon".

   But most of the time, instead of hitting the nucleus, most electrons just miss the nucleus of the tungsten atom. When the electron comes close to the nucleus, it is attracted to the nucleus and slows down, consequently an X-ray photon is released (due to the decrease in the kinetic energy of the photon).

   The electron that misses the nucleus continues to penetrate many such tungsten atoms producing many lower energy X-ray photons before it imparts all its kinetic energy. As a result General Radiation consists of X-rays of many different energies and wave lengths. It is also called Continuous Spectrum.

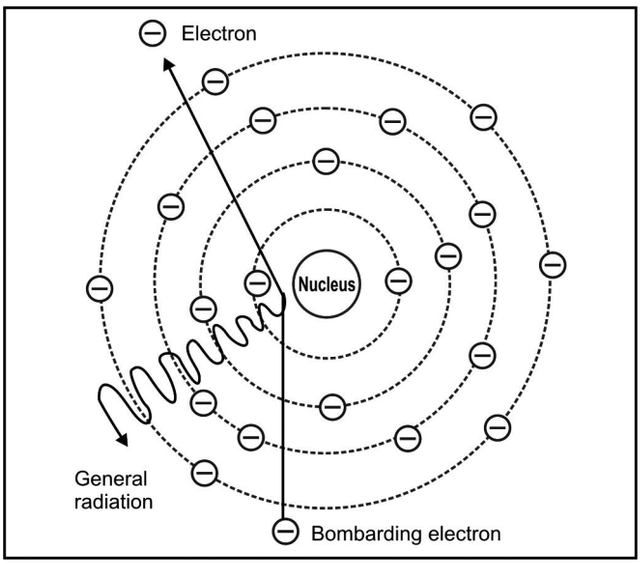


Fig. 4.16: When an electron that passes close to the nucleus of a tungsten atom is slowed down, an X-ray photon of lower energy known as general radiation results

b. Characteristic Radiation (Fig. 4.17): It is produced when a high speed electron dislodges an inner shell electron from the tungsten atom and causes ionization of the atom. Once the electron is dislodged the remaining

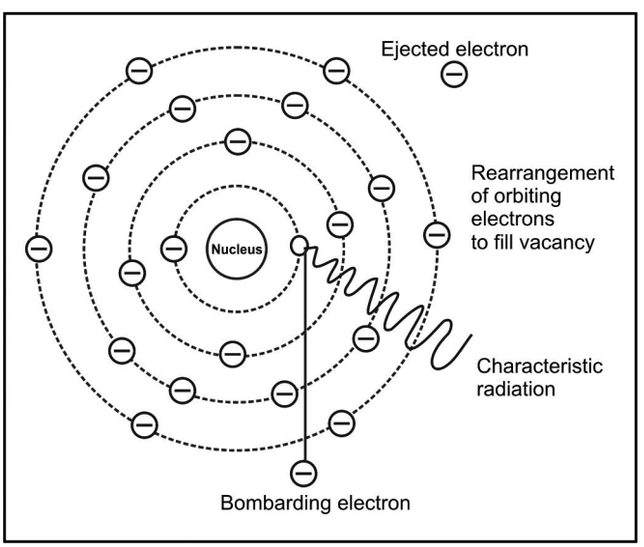


Fig. 4.17: An electron that dislodges an inner shell electron from the tungsten atom results in the arrangement of the remaining orbiting electrons and the production of an X-ray photon known as characteristic radiation

orbiting electrons are rearranged to fill the vacancy. This rearrangement produces a loss of energy that results in the X-ray photon, with the energy equal to the difference in the two orbital energy states. The X-ray thus produced is called Characteristic Radiation.

Characteristic radiation accounts for a very small part of X-rays produced in the dental X-ray machine and occurs only at 70 kVp and above, because the binding energy of 'K' shell electron is approximately 70 kVp.

The difference between the binding energy of the electrons will vary from element to element and thus, so will the energies of the photons emitted following ionization. The energy level values and their differences are characteristic of the element and the radiation emitted constitute the 'Line Spectrum', and is usually called the characteristic radiation of that elements.

BIBLIOGRAPHY

1. O'Brien RC. The Nature and Generation of X-rays. Dental Radiography: An introduction for Dental Hygienists and Assistants, 4th ed. Philadelphia, WB Saunders, 1982; 1-12.
2. WJ Merdith, JB Massey. Fundamental Physics of Radiology, Second edition, Bristol: John Wright and Sons 1972.

Section Three
Radiation and Health Physics

5

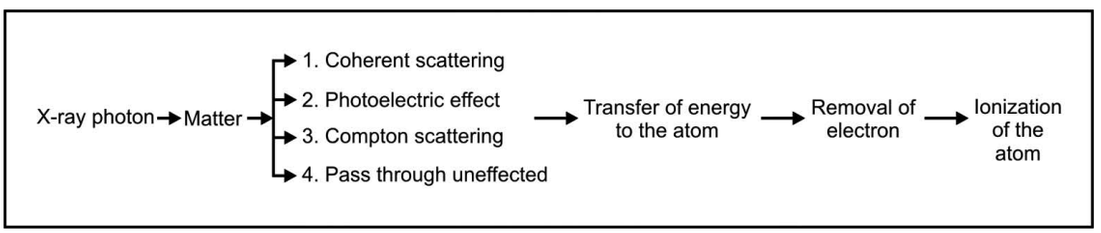
Radiation Biology

Radiation Biology is defined as the study of the effects of ionizing radiation on living systems.

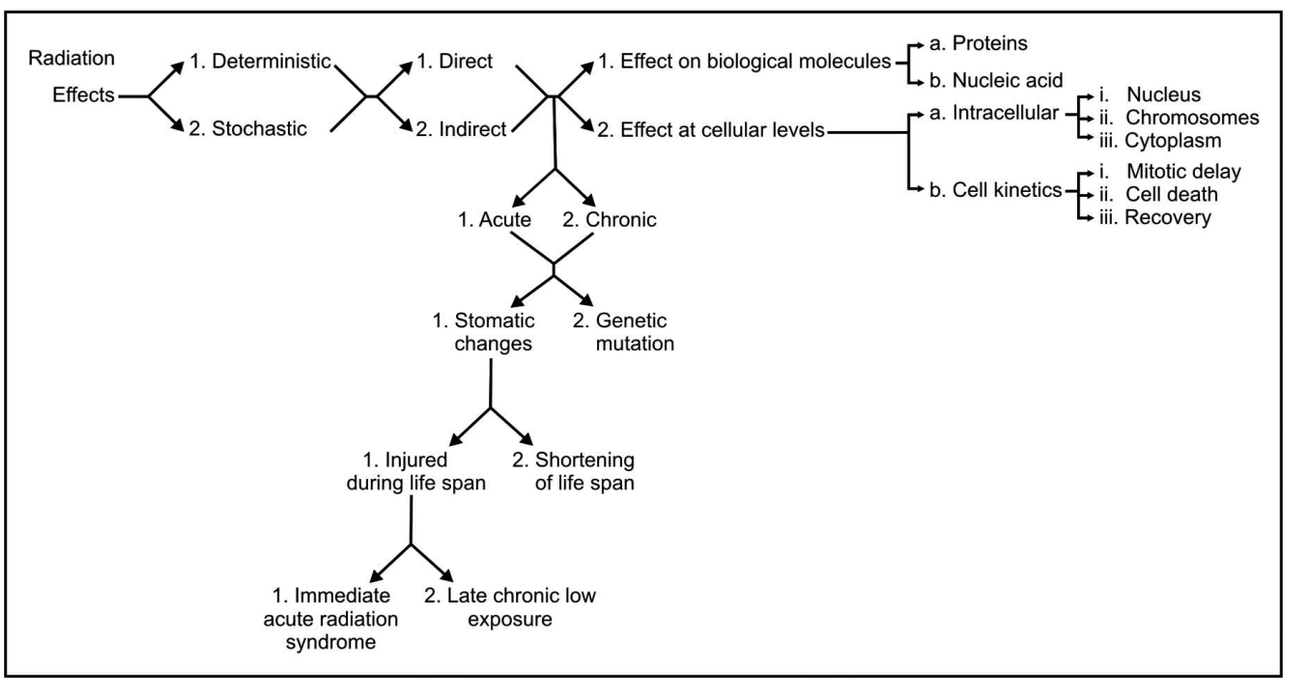
The initial interaction between radiation and matter occurs at the level of the electron. These initial changes are the basis for subsequent modification of biological molecules.

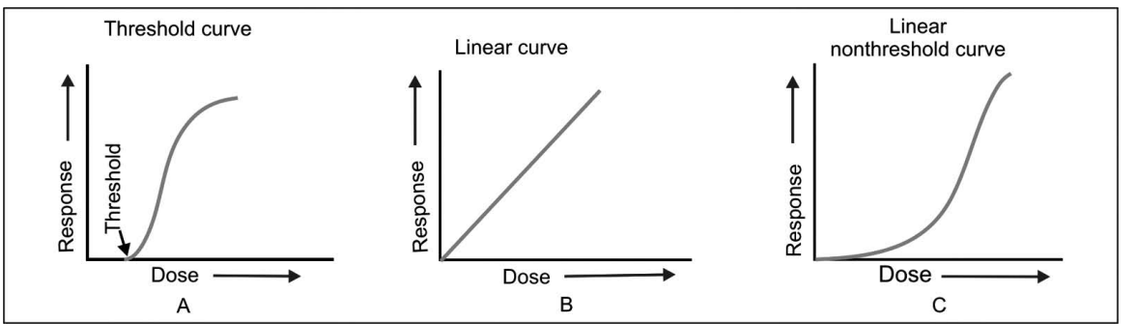
In turn these molecular changes may result in alteration in the cells and organism. These changes may persist for hours, decades or possibly for generations, or the changes may be so drastic that they may result in the death of the cell or organism.

Sequence of Events which Occur when an X-ray Photon Strikes Matter



Effect of Radiation on the Biological Tissues





Figs 5.1A to C: A. Threshold curve. This curve indicates that below a certain level (threshold), no response is seen. **B.** Linear curve indicates that the response is proportional to dose. **C.** Linear nonthreshold curve indicates that response is seen at any dose

Deterministic effect: Is an effect in which the severity of the response is proportional to the dose. These effects have a dose threshold below which the response is not seen. For example oral changes after radiation therapy. This effects usually in cell killing, and may occur in all people when the dose is large enough (Fig. 5.1).

Stochastic effect: It is that effect for which the probability of the occurrence of a change, rather than its severity is dose dependent. These effects do not have a dose threshold. For example radiation induced cancer, because the greater exposure of a person or population to radiation increases the probability of the cancer but not its severity.

Direct or Target Action Theory (Fig. 5.2)

Director or Target Action Theory is that effect which occurs when the energy of a photon or secondary electron ionizes biological macromolecules.

This states that the changes occur due to:

- Absorption of energy by biological molecules.
- Transfer of energy between unstable intermediate molecules.
- Formation of stable damaged molecules by disassociation or cross-linking.

The resultant molecules differ structurally from the original molecule hence the consequence is a biological change in the irradiated organism.

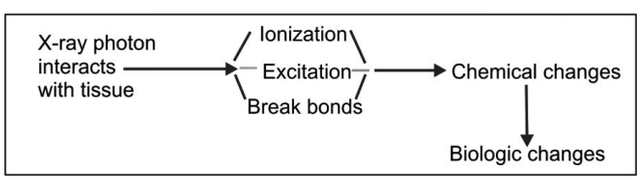


Fig. 5.2: The X-ray photon interacts with tissues and results in ionization, excitation or breaking of molecular bonds, all of which cause chemical changes which result in biological damage

Specific targets within the cell, probably the DNA or RNA in the nucleus take a direct hit from an incoming X-ray photon, or an ejected high energy electron, which breaks the relatively weak bonds between the nucleic acids. The subsequent effect includes:

- Inability to pass on information.
- Abnormal replication.
- Cell death.
- Only temporary changes- the DNA being repaired successfully before further cell division.

If the radiation hits some somatic cells, the effects on the DNA could result in radiation induced malignancy.

If the damage is to reproductive stem cells, the result would be radiation-induced congenital abnormalities.

What actually happens depends on several factors, such as:

- The type and number of nucleic acid bonds that are broken.
- The intensity and type of radiation.
- The time between exposures.
- The ability of the cell to repair the damage.

Indirect Action or Poison Chemical Theory (Figs 5.3 and 5.4)

Water is a predominant molecule of the biological system. When the photon is absorbed by the water molecule, it is ionized and releases free radicals which further interact and produce changes in the biologic molecule, this effect is termed 'indirect'.

Effect on Biological Molecules

- Proteins
  - Denaturation.
  - Inter- and intramolecular cross-linking.
  - Enzymes get inactivated leading to failure or conversion of substrate to product.

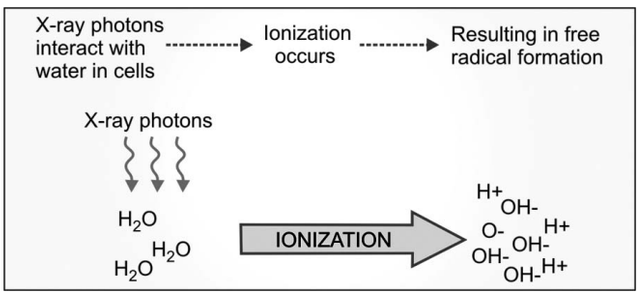


Fig. 5.3: Examples of free radicals created when water is irradiated

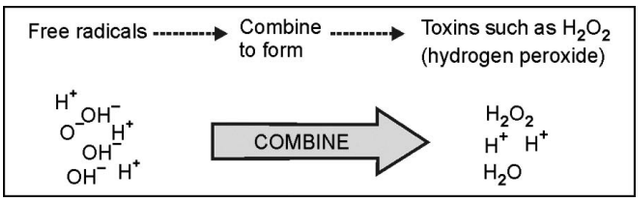


Fig. 5.4: Free radicals can combine with each other to form toxins such as hydrogen peroxide

- Nucleic acids
  - Change or loss of base.
  - Disruption of hydrogen bonds between DNA strands.
  - Breakage of DNA strands.
  - Cross-linking of DNA strands.

Effects at Cellular Levels

Intracellular

- Nucleus: inhibition of cell division.
- Chromosomes: single or double armed chromosomal aberrations (Fig. 5.5).
- Cell cytoplasm:
  - Increased permeability of plasma membrane to sodium and potassium ions.
  - Swelling and disorganization of mitochondria.
  - Focal cytoplasmic necrosis.

Effect on Cell Kinetics

This basically effects cell division and cell maturation process and depends upon:

- Dose of radiation
  a. High
  b. Low
- Period of radiation
  a. Acute
  b. Chronic
- Nature of dose of radiation
  a. Fractionalized
  b. At one time
- Interval period between doses

The effects seen are:

- Mitotic delay: Inhibition of progression of cell through the cell cycle (Fig. 5.6).
- Cell death: If damage is total there can be no recovery.
- Recovery: The capacity to recover depends on the above given factors.

Acute Exposure

This occurs when a large dose of radiation is absorbed in a short period of time, e.g. Nuclear accident.

The radiation damage caused by acute radiation is much more than that caused by chronic exposure to radiation.

This type of exposure is not seen when using Dental Diagnostic Radiations.

Chronic Exposure

This occurs when small amounts of radiations are absorbed repeatedly over a long period of time.

Somatic Damage

This damage occurs in the living cell/organism and is not carried forward once the cell/organism dies.

This can be observed as:

- Injuries during the life span
  - The most important are the radiation induced cancers. It is believed that radiation causes cancer by

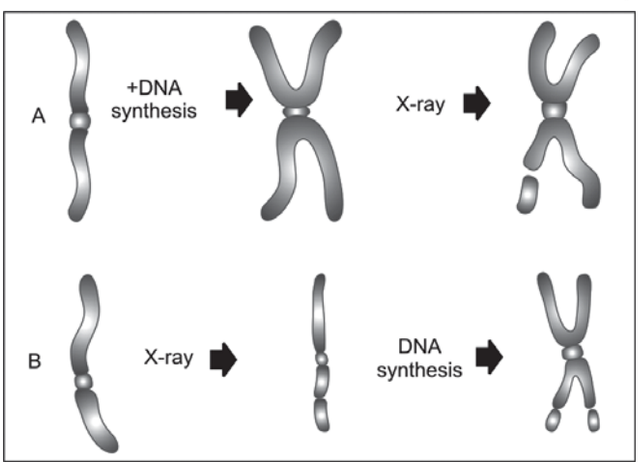


Fig. 5.5: Chromosome aberrations. A. Irradiation of the cell after DNA synthesis results in a single-arm (chromatid) aberration. B. Irradiation before DNA synthesis results in a double-arm (chromosome) aberration

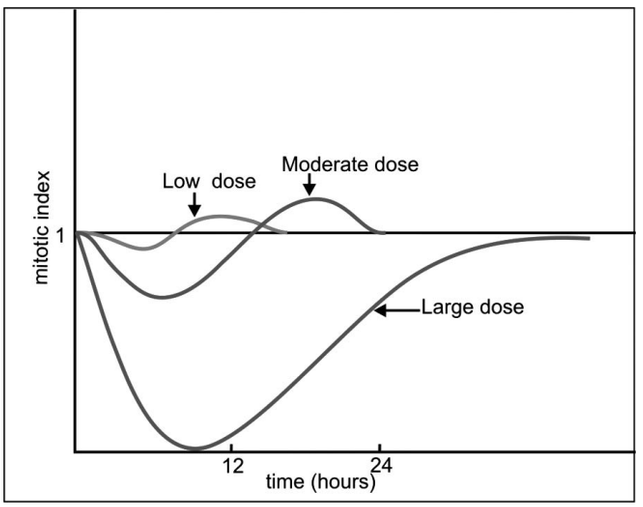


Fig. 5.6: Radiation-induced mitotic delay. The degree of delay in a replicating cell population depends on the amount of exposure. The larger the dose, the greater the reduction in mitotic activity and the more prolonged the recovery

modifying the DNA, still the exact mechanism of induction of cancer by ionizing radiation is not well understood. The most commonly found cancers are:

a. Thyroid cancer.
b. Esophageal cancer.
c. Brain and nervous system cancers.
d. Salivary gland cancers: The incidence is increased in patients treated for diseases of the head and neck. It was believed that the risk of salivary gland tumors may be highest in patients receiving full mouth examinations before the age of 20 years but it has been seen that this may be true only in individuals who have received a cumulative parotid dose of 500 mGy or more.
e. Cancer of other organs, like skin, paranasal sinuses and bone marrow also show excess neoplasia after exposure.
f. Leukemia.

– Other Late Somatic Changes:
  a. Growth and development is retarded subject to the age and amount of radiation the individual was exposed to.
  b. Mental retardation: as estimated 4 percent chance of mental retardation per 100 mSv exists at 8 to 15 weeks of gestation age.
     The exposure to the embryo from a full set of dental radiographs, using lead apron, is less than 3 mSv.
  c. Cataracts: the threshold for induction of cataracts is from 2 Gy to more than 5 Gy.

• Shortening the life span.

Genetic damage: Genetic cells are the germ cells found in the reproductive organs. These contain chromosomes which have genes which are made up of DNA.

Any damage will lead to loss or rearrangement of the genetic material, which results in genetic mutations.

These changes are more commonly seen in the next and subsequent generations.

Doubling dose: It is the amount of radiation a population requires to produce in the next generation as many additional mutations as arise spontaneously.

In humans the genetic doubling dose for mutations resulting in death is approximately 2 Sv.

Short-term Effects

These effects of radiation on a tissue are determined primarily by the sensitivity of its parenchymal cells.

If continuously proliferating cells are irradiated (bone marrow, oral mucous membrane), the effect of irradiation becomes apparent relatively quickly, (highly radio sensitive). Tissues composed of cells that rarely or never divide (muscle) demonstrate little or no radiation induced hypoplasia (low radiosensitivity) over a short-term.

Long-term Effects

The long-term deterministic effects of radiation on tissues and organs depend primarily on the extent of damage to the fine vasculature. The relative radiosensitivity of capillaries and connective tissue is intermediate. Irradiation of capillaries causes swelling, degeneration and necrosis, which increase capillary permeability and initiate progressive fibrosis around the vessels, leading to deposition of fibrous scar tissue and premature narrowing of vascular lumens. This impairs transport of oxygen, nutrients and waste products resulting in cell death, leading to progressive fibroatrophy of the irradiated tissue, and loss of cell function with a reduced resistance of the irradiated tissue to infection and trauma.

In India, around 40 percent of all cancers are detected as oral cancers. In addition for patients with cancer of the nose, nasopharynx, paranasal sinuses and oropharynx, radiotherapy is one of the modality of treatment used.

Radiotherapy is frequently used as an adjuvant form of treatment in the management of head and neck cancer. This radiotherapy may produce an oral sequelae that causes considerable misery to the patient.

Radiocurability: Is defined as the ability of radiations to reduce the number of malignant cells below a critical level such that no further clinical manifestation of their presence will occur during the remaining life time of the host.

Radiocurability of a tumor is related to its radiosensitivity regardless of its radioresponsiveness.

Radiosensitivity: Is defined as the ability of radiations to biologically change, (i.e. cell killing or a destruction of reproduction integrity) cells comprising a tumor or other tissue.

These changes manifest clinically as an alteration in the structure or function.

Radioresponsiveness: This refers to the time required for any changes to occur and can be measured in terms of the rate at which the clinical manifestations of radiation induced biologic change take place.

A tumor that shrinks rapidly following administration of any amount of radiation would be called radioresponsive.

Different cells of the same individual may respond differently to the same irradiation. Casarett has divided mammalian cells into five categories of radiosensitivity on the basis of histologic observations of early cell death.

1. *Vegetative intermitotic cells*: These are most radiosensitive. These cells divide regularly, have long mitotic futures and do not undergo differentiation between mitosis, have a short life span, e.g. early precursor stem cells such as those in spermatogenic or erythroblastic series, basal cells of the oral mucous membrane.
2. *Differentiating intermitotic cells*: These are less radiosensitive. They divide regularly but less often and undergo some differentiation between divisions, e.g. Intermediate dividing and replicating cells of the inner enamel epithelium of developing teeth, cells of hematopoietic series that are in the intermediate stages of differentiation, spermatocytes and oocytes.
3. *Multipotential connective tissue cells*: These have intermediate radiosensitivity. They divide regularly with limited differentiation, e.g. vascular endothelial cells, fibroblasts and mesenchymal cells.
4. *Reverting postmitotic cells*: These are radioresistant. They divide infrequently, have a long life span and die without dividing. These divide only under special conditions and are specialized in function, e.g. acinar and ductal cells of salivary glands and pancreas, and parenchymal cells of the liver, kidney and thyroid.
5. *Fixed postmitotic cells*: These are most radioresistant. These do not divide even in functional demand, e.g. neurons, striated muscle cells and squamous epithelial cells that have differentiated and are close to the surface of the oral mucous membrane.

The relative radiosensitivity of various organs is as follows:

High sensitivity: Lymphoid organs, bone marrow, testes, intestines, mucous membrane.

Intermediate sensitivity: Fine vasculature, growing cartilage, growing bone, salivary glands, lungs, kidneys, liver.

Low sensitivity: Optic lens, mature erythrocytes, muscle cells, neurons.

Factors Effecting Biologic Tissues

1. Nature of tissue irradiated.
   i. Radioresponsive.
   ii. Radioresistant.
2. Area irradiated: For the same dose, if a smaller area is irradiated, the effect of radiation is less.
3. Rate of dose: Smaller the dose, distributed over a large period of time results in a smaller or lesser effect of the radiation.
4. Fractionization: Division of the dose, with sufficient gaps, helps in tissue recovery resulting in lesser effect of the radiation.
5. Latent period: This is the period between the time of irradiation and the appearance of the effect.
6. Age of the patient: Younger the patient greater the chances of recovery.
7. Recovery power of the tissue: Undifferentiated cells have a greater power of recovery.
8. Type of cell: The effect of radiation is seen in the same generation if a somatic cell is effected, and in case of the genetic cell the effect of radiation will be seen in the next generation.
9. Type of irradiation: There are different types of irradiations—low energy, high energy or linear energy transfer.
10. Oxygenation: Greater oxygenation of the tissue, chances of recovery are greater, e.g. hyperbaric oxygen is used to treat radiation necrosis but it is important to note that the radioresistance of many biologic systems increases by a factor of 2 or 3 when irradiation is conducted with reduced oxygen (hypoxia).
11. Chemical protectors: Amino compounds or disulphides and amino groups, these act as free radical scavengers and prevent the damaging effects of organic free radicals.
12. Stage of development of the tissue: The effect of irradiation depends on the stage of development of the tissue, e.g. primitive and undifferentiated and still undergoing mitosis when irradiated the damage caused is greater.
13. Tissue threshold: Greater the tissue threshold, lesser the damage seen. This depends on the amount of radiation absorbed. Somatic changes do not occur until a minimum of tissue threshold is exceeded. Genetic changes occur with any given dose.

14. Part of the body exposed: The hazard of radiation is increased when a larger part of the body is exposed. Local or isolated part of the body may receive larger doses without risk, but the same dose given to the whole body may prove lethal.
15. Species and individuals: Different species respond differently. The median lethal dose varies in different species. Similarly in individuals of the same species the response may be variable. This variation of the Maximum Permissible Dose is approximately 50 percent.

In dental radiography the critical organs receiving scattered radiation include:

Bone marrow - 13 mR for full mouth intraoral periapical radiographs.

A maximum dose of 200 R is required for any damage to the marrow or blood forming organs. Hence, the risk of bone marrow damage from dental X-rays is small. The primary somatic risk from dental radiography is leukemia induction, especially in young individuals. This is because at birth all bones contain only red bone marrow, (one of the blood forming organs of the body), but with age some marrow changes to yellow (fatty) bone marrow, thus younger individuals are at a greater risk of developing leukemia.

Thyroid – 40 mR for full mouth intraoral periapical radiographs.

A dose of 10 R will produce thyroid cancer. All dental radiography gives scattered radiation to the thyroid, except cephalometry and curved surface tomography, where the thyroid is in the direction of the primary beam.

Gonadal – a single intraoral radiograph gives 100 to 900 mR to the face. From this;

Male gonads receive 0.3 mR.

Female gonads receive 0.03 to 0.001 mR, as these are placed internally.

A person on an average receives 0.3 mR by way of exposure from the sun and other radioactive materials. Thus, gonadal exposure is minimal with dental radiography.

The radiation to the gonads is principally via scattered radiation.

Eye – a series of full mouth intraoral periapical radiographs, will give only a few mR.

Cataract of the lens is produced after 500 R of exposure.

General Effects of Radiation

1. Skin: The reaction of the skin to radiation may be categorized as:
   i. Early or acute signs:
      - Increased susceptibility to chapping.
      - Intolerance to surgical scrub.
      - Blunting and leveling of finger ridges.
      - Brittleness and ridging of finger nails.
   ii. Late or chronic signs:
      - Loosening of hair and epilation.
      - Dryness and atrophy of skin, due to destruction of the sweat glands.
      - Progressive pigmentation, telangiectasis and keratosis.
      - Indolent type of ulcerations.
      - Possibility of malignant changes in tissue.

   All these changes in the skin are due to radiation trauma to:
      - The blood vessels.
      - Connective tissue.
      - Epithelium.

   Early erythema may appear from a single dose of about 450 rads.

   With lower doses no erythema occurs.
2. Hematopoietic injury: The usual picture of blood reaction to radiation is leukopenia, which in some cases may progress to leukemia, anemia, lymphopenia, and loss of specific immune response.
3. Eyes:
   - Epilation of eyelashes.
   - Inflammation, fibrosis and decreased flexibility of the eyelid.
   - Damage to the lacrimal glands, leading to dryness.
   - Ulceration of the cornea.
   - Initiation of cataract formation from the periphery towards the center.
4. Ears:
   - Columnar epithelium of the middle ear may be desquamated.
   - Edema of the mucosa and collection of sterile fluid in the middle ear, which leads to obstruction of the eustachian tube – Radiation Otitis Media.
   - Deafness due to rupture of the ear drums.
5. Testicles:
   - Suppression of germinal activity.
   - Alteration in fertility.
   - Functional changes in the offspring may be seen.
6. Ovary:
   - The various cells respond differently to irradiation.
   - Increase in frequency of hemangioma in children receiving dose of radiation *in utero*.
7. Oral mucous membrane:
   - Shows reddening and inflammation (mucositis).

- The next step is the breakdown, with the formation of white to yellow pseudomembrane.
- Sloughing of the mucosa.
- Secondary infection is very common.
- After termination of the therapy, the healing may be complete after about two months, but the mucous membrane tends to become atrophic, thin and relatively avascular, due to the obliteration of fine vasculature and fibrosis of the underlying connective tissue.
- Patient is usually prone to oral ulcerations and is unable to tolerate dentures.

8. Taste buds:
   These are sensitive to radiation and patient realizes a loss of taste in the second or third week of radiation therapy:
   - Posterior two-third of the tongue when irradiated effects the bitter and acid flavors.
   - Anterior third of the tongue when irradiated effects sweet and salty flavors.
     These changes in the taste perception may also be attributed to the salivary changes that occur due to radiation.
9. Salivary glands:
   The parenchymal component of the gland is sensitive to radiation. The gland demonstrates progressive fibrosis, adiposis, loss of fine vasculature and simultaneous parenchymal degeneration.
   - There is marked decrease in the salivary flow.
   - The composition of saliva is affected.
   - There is increased concentration of sodium, chloride, calcium, magnesium ions and proteins.
   - The saliva loses its lubricating properties.
   - The mouth becomes dry and tender due to xerostomia.
   - The pH of saliva is decreased which may initiate decalcification of enamel.
   - A compensatory hypertrophy of the salivary gland may take place and the xerostomia may subside after six to twelve months after therapy. The xerostomia that persists beyond a year is less likely to show return to normal.
10. Teeth:
    Adult teeth are resistant to the effects of radiation. When teeth are exposed to radiation in their developing stage, their development may be retarded.
    - Prior to calcification, the tooth buds get destroyed.
    - After initiation of calcification, there may be inhibition of cellular differentiation causing malformation or arrest of growth.
    - The pulp shows decreased vascularity, reduced cellularity and the tooth becomes more prone to pulpitis.

    Radiation caries: This is a rampant form of caries. These lesions occur secondary to changes in the salivary glands and saliva, due to the:
    - Decreased salivary flow.
    - Decreased pH of saliva.
    - Increased viscosity of saliva.
    - Decreased lubricating properties of saliva.

    All of the following leads to the decalcification of the enamel and increased accumulation of the food debris.

    Clinically three types of radiation caries are seen:
    i. Primarily involving cementum and dentin in the cervical areas. This lesion progresses around the tooth circumference and ultimately results in the amputation of the crown.
    ii. Generalized superficial lesions attacking the buccal, occlusal, incisal and palatal surfaces of the teeth.
    iii. Dark pigmentation of the crown.
11. Bone:
    - The primary damage to the mature bone is because of the damage to the fine vasculature which is already sparse in a dense bone such as the mandible.
    - Due to the loss of vasculature and hematopoietic elements, the marrow is replaced by fatty marrow and fibrous connective tissue.
    - The endosteum becomes atrophic, and shows lack of osteoblasts and osteoblastic activity.
    - The complication following irradiation is called osteoradionecrosis:
      – In this, the bone becomes hypovascular, hypocellular and hypomineralized, with decreased blood supply.
      – It is more often seen in the mandible than the maxilla, this is commonly attributed to the fact that the mandible has a single blood supply.
      – On the radiograph, osteoradionecrosis does not show any periosteal reaction as that seen in the case of osteomyelitis.
      – Osteoradionecrosis of the bone usually occurs due to infection or necrosis of the bone following tooth extraction or a chronic denture sore.
12. Whole body irradiation (Tables 5.1 to 5.3):
    When the whole body is exposed to low or moderate doses of radiation there are characteristic changes seen, called Acute Radiation Syndrome (Table 5.1); which

Table 5.1: Summary of the Main Acute Effects following large whole body doses of radiation. (Acute Radiation Syndrome)

Dose	*Whole body effect*
0.25 Sv	nil
0.25 – 1.0 Sv	Prodromal symptoms. slight blood changes, e.g. decrease in WBC count.
1 – 2 Sv	Mild hematopoietic symptoms. Vomiting in three hours, fatigue, loss of appetite, blood changes Recovery in a few weeks.
2 – 6 Sv	Severe hematopoietic symptoms. Vomiting in two hours, severe blood changes, loss of hair within two weeks, Recovery in one month to one year for 70%.
6 – 10 Sv	Gastrointestinal symptoms. Vomiting in one hour, intestinal damage, severe blood changes. Death in two weeks for 80-100%.
> 10 Sv	Cardiovascular and central nervous system symptoms. Brain damage, coma, death.

may be followed by death within one month. Individuals surviving ARS may show late somatic effects which may be seen as:

- Prodromal syndrome (1-2 Gy): Shortly after exposure the patient may develop nausea, vomiting, diarrhea and anorexia.
- Latent period: This is a period of apparent well being, the extent of which is dose related. Symptoms follow the latent period when the individuals are exposed in the lethal range (appx 2 to 5 Gy) or the supralethal range (more than 5 Gy).
- Bone marrow (hemopoietic) syndrome : (2 to 7 Gy) (Fig. 5.7): Here severe damage may be caused to the circulatory system. The bone marrow being radiosensitive, results in fall in the number of granulocytes, platelets and erythrocytes. Clinically this is manifested as lymphopenia, granulocytopenia and hemorrhage due to thrombocytopenia and anemia due to depletion of the erythrocytes.
- Gastrointestinal syndrome (7 to 15 Gy): This causes extensive damage to the gastrointestinal tract, leading to anorexia, nausea, vomiting, severe diarrhea and malaise.
  Injury to the basal cell epithelial cells of the intestines causes denuded mucosal surfaces, leading to loss of plasma and electrolytes, hemorrhage and ulcerations leading to diarrhea, dehydration and loss of weight. Finally leading to septicemia.
- Cardiovascular and central nervous system syndrome (more than 50 Gy): This produces death within one or two days. Individuals show intermittent stupor, incordination, disorientation and convulsions suggestive of extensive damage to the nervous system.

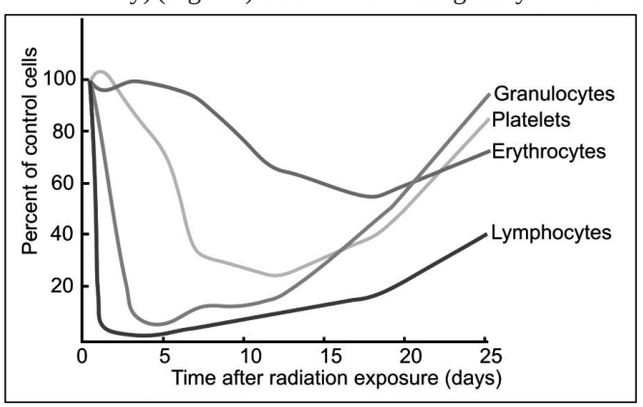


Fig. 5.7: Radiation effects on blood cells. When the whole body exposure inhibits the replacement of circulating cells by stem cell proliferation, the duration of the circulating cells survival is largely determined by their life span

Table 5.2: Comparative risks during pregnancy

Risk factor	*Result*	*Rate of risk*
Irradiation during gestation 10 mGy	Death from childhood leukemia	1 in 3,333
	Death from other childhood cancer	1 in 3,571
Maternal smoking 1 pack or more per day	Infant death	1 in 3
Maternal alcohol consumption	Signs of fetal alcohol syndrome	1 in 10
2 to 4 drinks per day	Major malformation at delivery	3 in 100

Modified from Mettler F, Moseley R. Medical effects of ionizing radiation, Orlando, Fla, 1985, Grune and Stratton

13. Shortening of the life span:
    The life span is diminished following brief whole body radiation exposure, or a small amount of radiation

Table 5.3: Susceptibility of different tissues to radiation-induced cancer

High	*Moderate*	*Low*
Colon	Breast (women)	Bladder
Stomach	Esophagus	Liver
Lung		Thyroid
Bone marrow (leukemia)		Skin
		Bone surface
		Brain
		Salivary glands

Table 5.4: The estimated risk per million of developing radiation-induced malignancy from various X-ray examinations

X-ray examination	*Risk per million of a fatal cancer*
*Dental intraoral	0.2
Chest (male)	0.27
Chest (female)	0.47
*Dental panaromic tomograph	1.0
*Skull	1.7
Lumbar spine	2.5
Pelvis	3.9
Abdomen	9.5
Barium meal	26.0
Barium enema	37.0
CT lung (male)	198.0
CT lung (female)	395.0

given over a long period of time. There is an accleration of the aging process resulting in a shortened life span.

14. Radiation effect on embryos and fetuses:
    Embryos and fetuses are considerably more radiosensitive than adults because most embryonic cells are relatively undifferentiated and rapidly mitotic. The fetus of a patient exposed to dental radiography receives less than 0.25 mGy from a full mouth examination when a leaded apron is used.

    The most sensitive period for inducing developmental abnormalities is during the period of organogenesis, between 18 and 45 days of gestation. These effects are deterministic in nature.

    Irradiation during the fetal period (more than 50 days after conception) does not cause gross malformations. However, general retardation of growth may persist through life. There is also an increased risk for childhood cancer, (leukemia and solid tumors), after irradiation *in utero*.

RADIOTHERAPY

Radiotherapy (radiation therapy) is the treatment of diseases using ionizing radiation. Ionizing radiation which is used for therapeutic purposes has high energy radiation in the megavoltage range.

Scope of radiotherapy: Radiotherapy is based on the principle that rapidly proliferating cells are more sensitive to ionizing radiation compared to the normal cell. This very property is used in the therapeutic treatment.

The malignant tumors may be classified in relation to radiation treatment:

1. Radiotherapy the treatment of choice.
   a. Tumors of Limited Sensitivity in Assessable Sites
      i. Carcinoma of the mouth, including tongue and lip
      ii. Carcinoma of the skin (of face and hands)
      iii. Carcinoma of the maxillary antrum
      iv. Carcinoma of the ethmoidal sinus
      v. Carcinoma of the middle ear
      vi. Intrinsic carcinoma of the larynx

   In this group cure rates are reasonably good if the growth is limited in extent. Good radiotherapy offers higher expectations of cure and less mutilation than good surgery. In later stages of these cancers radiation offers valuable palliation.

   b. Sensitive Tumors
      i. Sensitive sarcomas, e.g. lymphosarcoma, reticulosarcoma
      ii. Medulloblastoma of the cerebellum

   In the first case there is seldom a useful surgical alternative to radiotherapy. Children with medulloblastoma are ordinarily referred only after a surgical exploration.

   Cure is possible in a substantial percentage of these cases, where the disease is limited to one region of the body. Palliation remains possible up to a comparatively advanced stage of the disease.

   c. The Reticuloses and the Leukemia's
      i. Hodgkin's disease (lymphoadenoma)
      ii. Lymphofollicular reticulosis
      iii. Other reticuloses
      iv. Chronic myeloid leukemia
      v. Chronic lymphoid leukemia

   In this whole group the disease is systemic from the beginning and radiation is of major palliative and life prolonging value and thus the treatment of first choice. It may be linked with chemotherapy.

2. Radiation therapy and surgical extirpation both of value
   a. Predominantly surgical
      i. Secondary carcinoma in lymph nodes
      ii. Mixed tumor of the parotid
      iii. Tumors of the brain

   Radiotherapy is used either as a preoperative or as postoperative radiation. Palliative radiotherapy remains possible for most of the inoperable but not hopelessly advanced cases.

   b. Surgery and radiotherapy alternatives

   This is usually in the case of carcinoma of the body of the uterus, vulva, penis, skin of the trunk and limbs, and the decision has to be made for each case individually, having regard to all circumstances.

3. Radiotherapy indicated but of limited value

i. Carcinoma of the larynx (extrinsic)
ii. Carcinoma of the pharynx
iii. Thyroid tumors
iv. Malignant salivary gland tumors

In most of these tumors neither surgery nor radiotherapy offer more than limited percentage of cure. In the earlier stages of some of these growths radical radiotherapy should, however, be offered where the age and general condition of the patient is good. In the later cases of this group useful palliation is often possible for the relief of distressing symptoms but is contraindicated in the absence of symptoms.

4. Radiotherapy usually contraindicated
   a. Operable resistant types of growth
      i. Osteogenic sarcoma
      ii. Fibrosarcoma
      iii. Other resistant sarcomas (myosarcoma, liposarcoma, etc.)
      iv. Melanoma

   In this group, surgical excision is the treatment of choice, it should be radical and expect no help as a curative measure from radiotherapy.

   b. Treatment by radiotherapy not of value

   In cases like carcinoma of the stomach, intestine, colon or rectum, hypernephroma, carcinoma of the prostrate, secondary carcinoma in liver or lung, besides limited surgical treatment or hormonal therapy, treatment is of little value and so rarely provides real palliation.

Curative therapy: Here the intention is to eradicate the disease permanently in the treated area.

Palliative therapy: Here the aim is to achieve temporary improvement in the patients' condition in circumstances where experience has shown that cure is rarely possible.

The technical modalities used for clinical radiation therapy: (Figs 5.8 to 5.10)

1. External (transcutaneous) irradiation: Irradiation from sources at a distance from the body (X-ray, teletherapy with radium-226, cobalt-60, or cesium-137).
2. Local irradiation (Brachytherapy): Irradiation from source in direct contact with the tumor:
   i. Surface irradiation with applicators loaded with radioactive material (molds for treatment for certain oral tumors like carcinoma of the hard palate and skin tumors).
   ii. Intracavitary irradiation with radioactive material (most commonly radium-226, cobalt-60, cesium-137) in removable applicators which are inserted into body cavities, such as uterus, vagina, nasopharynx or maxillary sinus.
   iii. Interstitial irradiation by removable needles containing radium-226, cobalt-60, cesium-137; by nonremovable "seeds" of radioactive gold-198 or radon; by small radioactive iridium sources in nylon suture; or by radioactive tantalum-182 wire. The radioisotope are implated into the tumor, e.g. carcinoma of the tongue and buccal mucosa.
   v. Direct Roentgen therapy to epithelial lesions by means of cones (i.e. transvaginal, intraoral).

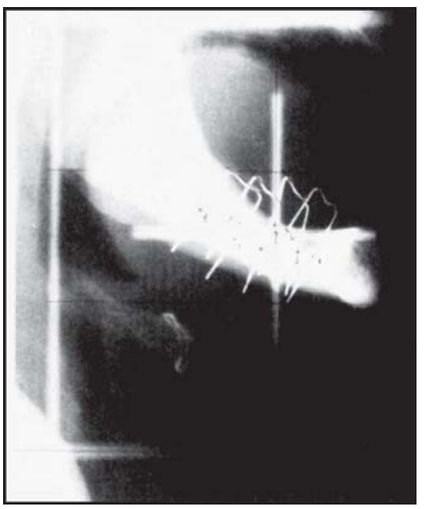


Fig. 5.8: Simulator verification film of lateral view of inserted iridium wire

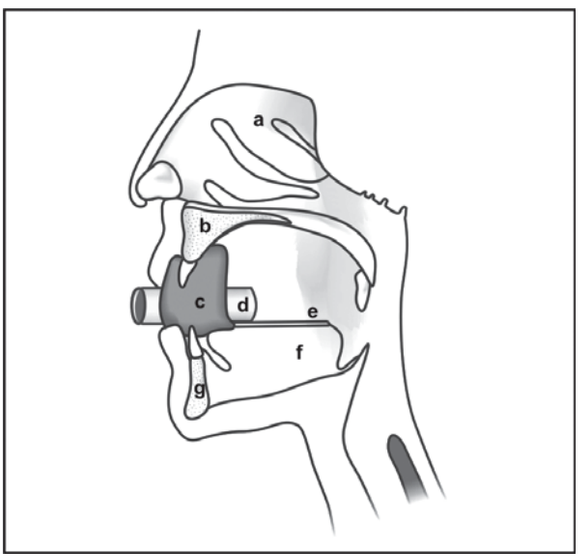


Fig. 5.9: Schematic diagram of the positioning device placed intraorally [a = nasal cavity; b = upper alveolus; c = wax impression; d = acrylic tube; e = acrylic tongue depressor; f = tongue, g = lower alveolus.]

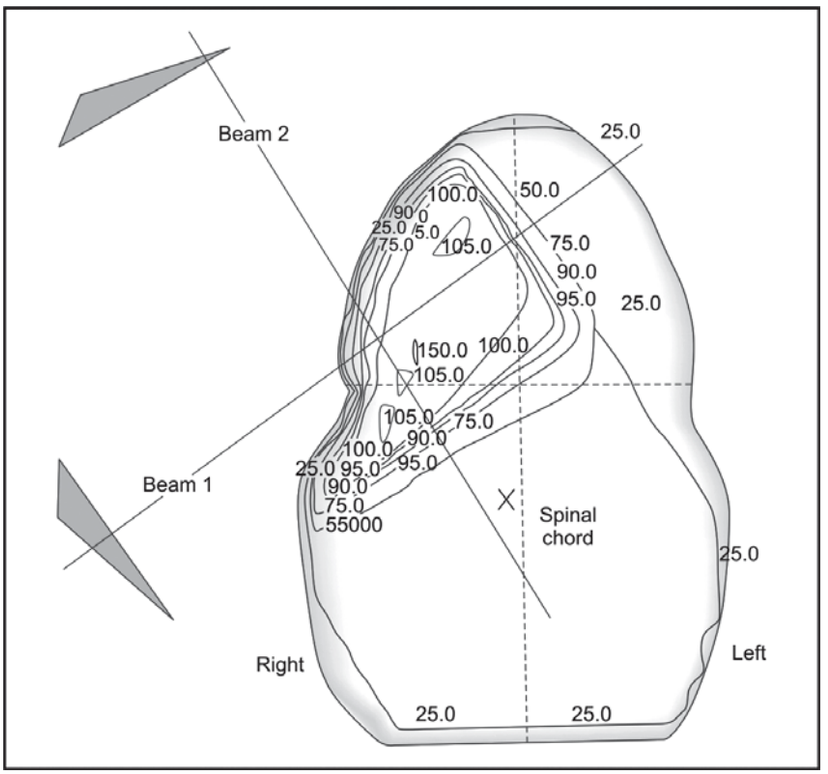


Fig. 5.10: Floor of mouth radiation isodose distribution for lateralized tumor; anterior and posterior oblique fields

3. Internal or systemic irradiation: Irradiation by radioactive sources (i.e. 32 P, 131 I) administered intravenously or parenterally. Radioactive Iodine is used to treat thyroid cancer, and Phosphorus-32 is used for the treatment of polycythemia vera.

RADIOBIOLOGY

The ionizing radiation when passes through the tissue of a patient affects the biology of both normal and tumor tissues. This radiation causes both direct and indirect effects on biologic targets. Radiation kills cells by interaction with the

Table 5.5: Modalities for Clinical Radiation Therapy

External irradiation	*Surface*	*Local irradiation intracavitary*	*Interstitial*	*Internal or systemic irradiation*
See Table 5.6	Radium-226 and strontium-90 in plaque (skin) and in needles and tubes for use in molds (skin, lip, floor of mouth)	Radium-226, cobalt-60, and cesium-137 in needles and tubes for use in special applicators for the cervix, vagina, uterine cavity, bladder, paranasal sinuses X-ray through a cone in the vagina or oral cavity. Isotopes i.e. colloidal 198 Au, or 32 P for instillation in serous cavities	Radium-226, Cobalt -60 and Cesium-137 needles, Tantalum-182 wire, and Iridium-191 seeds in a ribbon for temporary (removable) implantation Radon and gold seeds for nonremovable (permanent) implantation	32 P 131 I

Table 5.6: Modalities for External Irradiation

Term	*Voltage*	*HVL*	*Source*
Low voltage (superficial)	85-140 kv	1-3 mm Al	X-ray
Medium voltage (orthovoltage)	180-400 kv	0.5-3 mm Cu	X-ray
Super voltage	500 kv-8 mv	4-15 mm Cu	X-ray Radium-226 Cobalt-60 Cesium-137
Mega voltage	Above super voltage energy		Specific generators, e.g. betatron, synchroton, linear accelerator

water molecules in the cells, producing charged molecules that disrupt the biochemical processes in the cells. The DNA of a cell may be directly affected by the secondary electrons generated as ionizing radiation interacts with tissue. The radiation may also have an indirect effect due to the formation of free radicals, these free radicals in turn cause most of the chemical damage to the DNA. In addition there are a number of other cellular functions that are disrupted by radiation induced damage. Chromosomal damage also occurs. This damage is modified by oxygen concentration, temperature and other intracellular components.

The basic aim of radiotherapy is to destroy the tumor, but to preserve adjacent normal tissue. Ionizing radiation deposits energy that injures or destroys cells by damaging their genetic material, making it impossible for these cells to continue to grow. The lethal dose for both normal and abnormal tissue is the same, but normal tissue has a greater ability to repair sublethal damage between doses of radiation than neoplastic cells.

Preparation Procedure for External Irradiation

1. Mould and Mould Room: These are made for head and neck irradiation to immobilize the treatment part and to mark the radiation field.
2. Simulation: An X-ray machine having all the mechanical functions of a therapy machine is used.
3. Planning: The time between simulation and starting the treatment is used to plan the treatment using the data collected in the simulator and from a CT scan, which is transferred to the planning computer where the appropriate calculations are done. This assures the attainment of the prescribed radiation dose to the tumor cells while the dose to the normal tissue is kept to the minimum. During this process the patient is positioned as for the treatment and the site of treatment is clearly identified and marked on the mould or tattooed on the patient's body.
4. If a patient is anemic, blood transfusions may be given to increase the amount of oxygen in the blood.
5. Protection: Blocks and shields made of lead ensure that radiation reaches only the target tissue. Port films are X-ray pictures taken during treatment to ensure the precision of targeting and so is 3-D computer soft ware. Shielding is mandatory for the following organs after receiving the tolerance dose: Brainstem and Spinal Cord- above 45 Gy, Mandible and TM Joint- above 70 Gy, Temporal Lobe- above 60 Gy.
6. External radiation therapy is often given as a series of short daily treatments in the radiotherapy department using teletherapy machine (telecobalt/linear accelerator).

Fractionation of Radiotherapy

Fractionation helps to minimize normal tissue reaction. The clinical effects of fractionated radiotherapy are influenced by the ability to **r**epair sublethal damage, **r**eoxygenation of the tumor during the course of radiation, **r**epopulation of the tumor and normal tissues between fractions and **r**edistribution of the cells into a more sensitive phase in the cell cycle treatment. (The four **"r's"** of radiobiology).

The various types of fractionation are:

1. Conventional fractionation; is the application of daily doses of 180-200 cGy and 5 fractions per week to a total dose of 40-70 Gy depending on the tumor type.
2. Hyperfractionation; two or more fractions per day of reduced dose (115-120 cGy) with overall treatment time similar to conventional fractionation.
   This helps to increase the total dose without increasing the late reactions.
3. Accelerated fractionation; is a means of decreasing the overall duration of treatment in an effort to reduce the repopulation of tumor cells in rapidly proliferating tumors. Tumor repopulation or regeneration occurs during treatment when the overall duration of treatment is increased. Shortening of overall treatment time can increase the tumor control in selected situations.
4. Accelerated hyperfractionation; is method of delivering two or more fractions per day of normal dose per fraction which helps in reducing the overall treatment time without increasing the risk of late complications.
5. Concomitant–Boost technique; is a variant of accelerated fractionation, where the treatment is delivered once daily for the first three and a half weeks and then twice

daily for the remaining two and a half weeks, when the tumor can begin to repopulate more rapidly.
6. Hypofractionation; in this method less than four fractions per week with higher dose per fraction than what is conventionally given are planned. This method is found to be useful in selective cases, e.g. treatment of melanomas.
7. Split course therapy; this treatment is given in a small course with a rest period in between.

Advantages of Radiotherapy

1. No tissue or functional loss.
2. Better cosmetic outcome compared to surgery.
3. Control of subclinical disease in the regional nodes is possible without added morbidity.
4. Can simultaneously treat multiple primaries.
5. Better surgical salvage of radiotherapy failures than radiotherapy of surgical failures.
6. Rare treatment related mortality.
7. The lesion can be treated *in situ* and the need for tissue removal is avoided, it is the treatment of choice in T1 and T2 tumors.
8. External beams can be used in such a way, as to protect adjacent, uninvolved tissues, with enhanced effects, using smaller boost fields or combining external beam and interstitial techniques.
9. Treatment of primary tumors of the posterior third of the tongue, oropharynx and tonsillar pillars is easily treated by radiotherapy and surgery is only done for the nodal involvements.

Disadvantages of Radiotherapy

1. Undesirable acute side effects such as painful mucositis, loss of taste, dryness of mouth, etc.
2. Potential late complications of soft tissues and bone.
3. Development of secondary tumors.
4. Protracted treatment course.
5. Requires good infrastructures.

Recent Developments in Radiotherapy

1. Modification of tumor hypoxia; using hyperbaric oxygen, bioreductive nitroimidazole drugs (mimic oxygen with greater tissue perfusion characteristics; misonidazole, etanidazole), nicotinamide (causes vasodilatation and reduces transient or acute hypoxia).
2. Use of modified radiation fractionation.
3. Combined chemotherapy/radiotherapy.
4. Combined modified radiation fractionation and simultaneous chemotherapy.
5. Conformal radiotherapy and intensity modulated radiotherapy.

BIBLIOGRAPHY

1. Allan B. Reskin. Advances in Oral Radiology. PSG Publishing Co. 1980.
2. Barr JH, Stephens RG. Radiological Health. In Dental radiology. Pertinent Basic Concepts and their Applications in Clinical Practise. Philadelphia, WB Saunders, 1980; 66-80.
3. Baumann M, Saunders M, Joiner MC. Modified Fractionation in Basic Clinical Radiobiology. Ed. Steel GG, 2002; 147.
4. Bushong SC. Radiologic Science for Technologist, Physics, Biology and Protection, 7th ed, St. Louis, Mosby 2001.
5. Dowd SB, Tilson ER. Practical Radiation Protection and Applied Radiology, 2nd ed, Philadelphia, WB Saunder 1999.
6. Frommer HH. Biological effects of radiation, In Radiology for Dental auxillaries, 6th edition St. Louis, Mosby- year book, 1996; 49-67.
7. Goaz PW, White SC. Health Physics. In Oral Radiology, Principles and Interpretation, 3rd ed. St. Louis, Mosby- year book, 1994; 48-68.
8. Hall EJ. Radiobiology for the Radiologist, 5th ed. Baltimore, Zero Lippincott, William and Wilker.
9. Johnson ON, McNally MA, Essay CE. Effects of Radiation Exposure, In essentials of dental radiography for assistants and hygienists, 6th ed. Norwalk, Appleton and Lange, 1999; 87-105.
10. Mason-Hing LR. In Fundamentals of Dental Radiography, 3rd ed., Philadelphia, WB Saunders, 1993; 221-29.
11. Meredith WJ. Fundamental Physics of Radiology, 2nd ed., John Wright and Sons Ltd 1972.
12. S Dru Forrester. Principles of cancer management Part II, Surgery, Radiotherapy, Hyperthermia, Immunotherapy, 1997.

6

Protection from Radiation

Research studies measuring the risk of X-ray exposure for increased occurence of cancer, birth defects, cataracts and life span shortening have been controversial and are not conclusive, while clinical cases of radiation damage from dental X-rays have not been reported. It cannot be proved that there is no possibility of a hazard to the patient. This situation has produced the concept of keeping radiation exposure "as low as reasonably achievable" – The ALARA Principle, which recognizes the possibility that no matter how small the dose is, some stochastic effect may result.

The application of radiation protection principles is called Health Physics.

RADIATION PROTECTION

The principal of radiation protection is to do those things that will minimize exposure of patient and dental personnel and still provide benefits for the patient from use of diagnostic radiography.

PROTECTION IN GENERAL

For a given radiation source the amount of radiation at any point in the beam depends upon the distance from the point to the source of radiation (Intensity is inversely proportional to the square of the distance) and the nature of thickness of the material through which the radiation is passed.

In addition, the average person is exposed to an additional 0.76 to 1.01 mSv per year from other sources, such as global fall out, occupational exposure, treatment and diagnostic radiation procedures and other miscellaneous causes.

Sources of Radiation Exposure

A wide variety of conditions and circumstances result in radiation exposure, they may be broadly classified into; (Fig. 6.1)

Natural or Background Exposure

Exposure to radiation from natural sources is known as background exposure. This radiation comes from a variety of sources.

a. *External*:
   i. Cosmic (non terrestrial): These include energetic subatomic particles, photons of extraterrestrial origin that reach the earth (primary cosmic radiation) and to a lesser extent the particles and photons (secondary cosmic radiation) generated by the interactions of primary cosmic radiations with atoms and molecules of the earth's atmosphere.

      Cosmic radiation also includes exposure resulting from airline travel.

   ii. Terrestrial: Exposure comes from radioactive nuclides in the soil, (potassium - 40), and from radioactive decay products of uranium-238 and thorium-232.

      The total of much more than 13 mSv per year, (*102 mrem/ year*) represents the national average in India.

b. *Internal*: These are radiations from radionuclides that are taken up from the external enviroment by inhalation

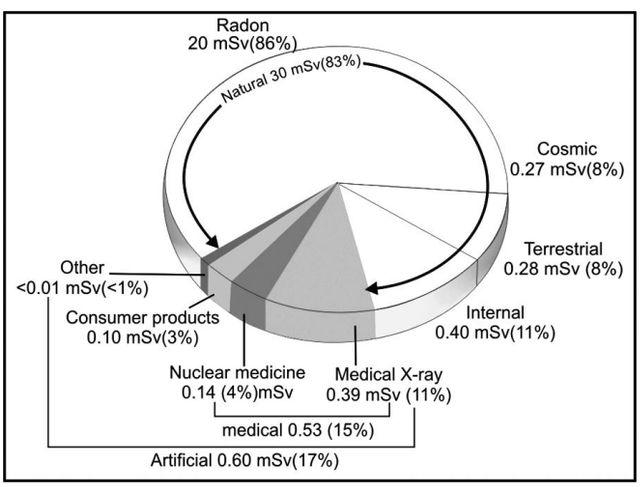


Fig. 6.1: The distribution of natural and artificial radiation. Natural radiation contributes more exposure than artificial radiation, medical X-ray diagnosis is the largest component of artificial radiation

and ingestion. This accounts for approximately 67% of the radiation exposure of the population.

i. Radon is a decay product in the uranium series.
ii. Other internal sources is the second largest source (11%) of natural radiation which results from the ingestion of food and water that contain radionuclides.

Artificial Radiations

Are a result of the technological advances made by man, they are:

a. *Medical*:
   i. X-ray diagnosis.
   ii. Nuclear medicine.
b. *Consumer products*:
   i. Occupational.
   ii. Nuclear fuel cycle fall out.
   iii. Miscellaneous.

Although the risk involved with dental radiography is small they are a common part of every day life. Despite the fact that the diagnostic radiation appears to be a weak carcinogen, the risk is increased because a large number of people are exposed. It is the responsibility of the practitioners to ensure that the patients avoid even the smallest unnecessary dose of radiation (Table 6.1).

The magnitude of biological effects produced depends upon how much radiation energy is absorbed by the irradiated material and hence the objective of X-ray dosimetry is the measurement of energy absorbed in any material with particular references on biological tissue.

Dosimetry

Dosimetry is the determination of the quantity of radiation exposure or dose. (Table 6.2)

Radiation dosimetry: Deals with the measurement of the absorbed dose or dose rate resulting from the interaction of ionizing radiation with matter and particularly in different tissues of the body.

Dose: It is amount of radiation at a given point or the amount of energy absorbed per unit mass at the site of interest.

Erythema dose: It is that dose which produces in one sitting a reversible reddening of the skin (3-4 Gy).

Table 6.1: Effective dose, equivalent natural exposure, and probability of stochastic effects from diagnostic X-ray examinations

Survey	*E (μSv)*	*Days of equivalent natural exposure*	*Probability of stochastic effects (× 10^{-6})*
Intraoral			
Round collimation, D-speed film*			
Periapical—15 films	111	13.9	8.1
Interproximal—4 films	38	4.8	2.8
Complete mouth survey—19 films	150	18.8	11.0
Rectangular collimation, E-speed film†			
Complete mouth survey—20 films	33	4.1	2.4
Extraoral			
Panoramic‡	26	3.3	1.9
Computed tomography			
Maxilla	104§ to 1,202‖	13.0 to 150.3	7.6 to 87.7
Mandible	761§ to 3,324‖	95.1 to 415.5	55.6 to 242.7
Lower gastrointestinal (GI)¶	4060	507.5	55.6 to 242.7
Upper GI¶	2440	305.0	178.1
Abdomen¶	560	70.0	40.9
Skull¶	220	27.5	16.1
Chest¶	80	10.0	5.8

*Avendanio B, et al. Effective dose and risk assessment from detailed narrow beam radiography. Oral Med Pathol Radiol Endod 1996; 82:713.
†White SC. Assessment of radiation risks from dental radiography. Dentomaxillofac Radiol 1992;27:118.
‡Frederikson NL, Benson BS, Sokolowski TW. Effective dose and risk assessment from film tomography used for dental implant diagnostics. Dentomaxillofac Radiol 1994;23:123.
§Frederikson NL, Benson BS, Sokolowski TW. Effective dose and risk assessment from computed tomography of the maxillofacial complex. Dentomaxillofac Radiol 1995;24:55.
¶Scaf G, et al. Dosimetry and cost of imaging osseointegrated implants with film-based and computed tomography. Oral Surg Oral Med Pathol Oral Radiol Endod 1997;83:41.
¶National Council on Radiation Protection and Measurements: Exposure of the US population from diagnostic medical radiation. NCRP Report 100, Bethesda, Md, 1989.

Table 6.2: Summary of radiation quantities and units

Quantity	*SI unit*	*Traditional unit*	*Conversion*
Exposure	Air kerma	Roentgen (R)	1 Gy = 100 rad 1 rad = 0.01 Gy (1cGy)
Absorbed dose	Gray (Gy)	Rad	1 Gy = 100 rad 1 rad = 0.01 Gy (1cGy)
Equivalent dose	Sievert (Sv)	Rem	1 Sv = 100 rem 1 rem = 0.01 Sv (1cSv)
Effective dose	Sievert (Sv)	—	—
Radioactivity	Becquerel (Bq)	Curie (Ci)	1 Bq = 2.7×10^{-11} Ci 1 Ci = 3.7×10^{10} Bq

Table 6.3: Tolerance dose of different organs

Organ	*App. tolerance dose*
• Skin	60 Gy / 5 weeks (in 30 sittings)
• Epiphysis (condyles)	5 Gy / 3 weeks.
• Brain, liver, kidney, lungs	40 Gy / 3 weeks.
• Eyes:	not more than 50 Gy / 3 weeks.
• Gonads:	not more than 4 Gy in a single dose.
i. Male gonads	0.003 Gy
ii. Female gonads	0.005 Gy

Exposure It is a measure of radiation quantity, the capacity of the radiation to ionize air.

The SI unit of exposure in air is kerma (Kinetic Energy Released in Matter).

Kerma measures the kinetic energy transferred from photons to electrons and is expressed in units of dose gray (Gy), where 1 Gy equals 1 joule/kg.

Kerma is the sum of the initial kinetic energies of all the changed particles liberated by uncharged ionizing radiation (neutrons and photons) in a sample of matter, divided by the mass of the sample. It has replaced the Roentgen (R), the traditional unit of radiation exposure measured in air.

[*Roentgen (R): is the quantity of X or gamma radiation such that the associated corpuscular emission through 0.00123 gms of air at 0°C or 760 mm of mercury produces in air ions carrying 1 electrostatic unit of electric charge of either positive or negative charge.*
R: was used to measure the intensity of radiation.
The roentgen was useful in describing the energy of an X-ray beam at a given spot and was used in dentistry to quantitate X-ray exposure at the skin of the patient.
For many years the Roentgen was used both as a unit of radiation in quantity as well as a unit of absorbed energy (dose). This was not acceptable for biological tissues since roentgen was measured in air and a different unit was needed for tissues, since tissues are more dense than air and also vary in density amongst themselves and therefore their ionization differs from that of air]

Absorbed dose: It is the measure of the energy absorbed by any type of ionizing radiation per unit mass of any type of matter.

$$\text{Absorbed dose} = \frac{Ed}{m} \text{ where;}$$

Ed is the energy imparted by an ionizing radiation to the matter in a volume of element.

m is the mass of matter in that volume of element.

In 1975, the SI unit is the Gray (Gy), was introduced which replaced the traditional unit Rad, where 1 Gy equals 1 joule/kg.

[*Rad (r): It is the unit of absorbed radiation. (Radiation Absorbed Dose)*
It is the production of 100 ergs of energy in 1gm of tissue by any form of ionizing radiation.
It is replaced by a new unit Gray
1 Gy = 1 joule/Kg = 100 r
1 Gy = 100 rad]

Different types of radiations, i.e. X-rays, gamma rays, electrons, protons and alpha particles produce different degree of biological effects in tissues with the same dose or amount of energy deposited in tissue. In order to measure all types of radiation for biological effect with the same measurement, a separate unit called the Equivalent Dose is used.

Equivalent dose (H_T): It is used to compare the biologic effects of different types of radiation to a tissue or organ. It is the sum of the products of the absorbed dose (D_T) averaged over a tissue or organ and the radiation weighting factor (W_R);

$$H_T = \Sigma W_R \times D_T$$

Equivalent dose is expressed as a sum to allow for the possibility that the tissue or organ is exposed to more than one type of radiation. The radiation weighting factor is chosen for the type and energy of the radiation involved. Thus high –LET radiations (which are more damaging to the tissue

than low-LET radiations) have a corresponding higher W_R, e.g. the W_R of photons is 1;

of 5 keV neutrons and high –energy protons is 5;

of alpha particles is 20.

The unit of equivalent dose is Sievert (Sv).

For diagnostic radiology 1 Sv equals 1 Gy.

The traditional unit of equivalent dose was 'rem'.

[*Rem (Rad Equivalent Mammal): It is the unit of dose equivalent. This unit is used to facilitate comparison between biological effects of exposure and various types of radiations.*
1 Sv = 100 rem]

Effective Dose (E): It is used to estimate the risk in humans. It is the sum of the products of the equivalent dose to each organ or tissue (H_T) and the tissue weighing factor (W_T)

$$E = \Sigma H_T \times W_T$$

The unit of effective dose is Sievert (Sv).

Quality Factor (QF): It relates all radiation to biologic systems in terms of its biological effects relative to standard exposure of X-rays.

E.g. In some systems a dose of 0.1 rad caused by fast neutrons has the biological effect as 1.0 rad of X-rays.

Therefore, QF = 10 (1.0/0.1) = 10 (10).

[*For radiations used in dental radiology, it is sufficiently accurate for protection calculation to assume that an exposure of 1 R will result in an absorbed dose of 1 Rad which will produce a dose equivalent of 1 Rem. Thus,*

In diagnostic radiology : 1R = 1 *r* = 1 rem

An exception is in the case of the bony structures of the head where an exposure of 1R will result in an absorbed dose of 3 Rads and dose equivalent of 3 rem, because of greater absorption]

Relative Biological Effectiveness (RBE): It's application is only in laboratory investigations and studies. It is the unit of measuring radioactivity of a substance.

It corresponds to 3.7 × 10^{10} disintegrations per second, the activity of 1 gram of radium, which was called Curie (Ci)]

It is now replaced by becquerel (Bq).

Maximum permissible dose (MPD) = It is equal to 0.05 Sv/year.

This is the equivalent that a person or specified parts of the person shall be allowed to receive in a stated period of time. For:

i. Average weekly exposure for either patient or operator, is 0.001 Sv.
ii. A maximum of 13 week exposure is 0.05 Sv. Should an operator receive more than 0.05 Sv in any 13 week period, he should avoid any further X-ray exposure until his total for the year falls below what he would have received at a rate of 0.05 Sv/year.
iii. For the general public the maximum permissible dose is limited to 1/10th or 0.005 Sv/year.

Operator Accumulated Dose (OAD):

This is equal to 5(N – 18)

where N = the age of the patient

OAD is also called *MAD* or *Maximum Accumulated Dose*.

This indicates that higher limits permitted for occupationally exposed persons do not pertain to individuals under the age of 18 and dental assistants under the age of 18 are limited to the same exposure as the general public, that is 0.005 Sv/year.

The NCRP and ICRP have established guideline on the amount of radiation received by occupationally exposed individuals and the public; (Table 6.4. Recommendations to the annual limits for Human Exposure to Ionizing Radiations).

Although 50 mSv of whole body radiation exposure in 1 year is a result of performing one's occupation, every effort should be made to keep the dose of all individuals as low as possible.

A full mouth radiographic examination will produce gonadal dose to;

Males: app. 1 mSv or less. (more from maxillary views, which are angled caudally)

Female (ovaries): is 50 times less, app. 0.02 mSv.

Radioactivity: This is based on the decay rate of a sample of radioactive material and it's unit of measurement is called Curie (Ci).

[*A Curie corresponds to 3.7 × 10^{10} disintegrations per seconds*]

It is now replaced by becquerel (Bq) one becquerel equals one disintegration per second.

In intra oral radiography the mean skin exposure per single dental film is:

360 mR for periapical

325 mR for bitewing.

Studies have shown that the exposure to any specific area of the patients face is much less than the total radiation output at the tip of the cone.

The studies also revealed that the patient exposure with the long cone technique is significantly less than the short cone technique at the same operating kilo voltage.

In Panaromic Radiography the patient dose is less than that for a full mouth series of intra oral peri apical films.

The bone marrow dose from panoramic radiography is equivalent to that received from one to two weeks of background exposure.

Table 6.4: Recommendations on annual limits for human exposure to ionizing radiation

Recommendation	*NCRP*	*ICRP*
Occupational dose limits		
Relative to stochastic effects	50 mSv annual effective dose limit and [10mSv][age(yr)] cumulative effective dose limit	50 mSv annual effective dose limit and 100 mSv in 5 yr cumulative effective dose limit
Relative to deterministic effects	150 mSv annual equivalent dose limit to lens of eye and 500 mSv annual equivalent dose limit to skin and extremities	150 mSv equivalent dose limit to lens of eye and 500 mSv annual equivalent dose limit to skin and extremities
Nonoccupational (Public) dose limits		
Relative to stochastic effects	5 mSv annual effective dose limit for infrequent exposure and 1 mSv annual effective dose limit for continuous exposure	1 mSv annual effective dose limit and, if higher, not to exceed annual average of 1 mSv over 5 yr
Relative to deterministic effects	50 mSv annual equivalent dose limit to lens of eye, skin, and extremities	15 mSv annual equivalent dose limit to lens of eye and 50 mSv annual equivalent dose limit to lens of eye, skin, and extremities
Embryo-fetus	0.5 mSv equivalent dose limit per month after pregnancy is known	2 mSv equivalent dose limit after the pregnancy has been declared
Negligible individual dose*	0.01 mSv annual effective dose	None established

From National Council on Radiation Protection and Measurements: NCRP Report 116, 1993, and International Commission on Radiological Protection: Radiation protection, ICRP Publication 60, 1990.

*That dose below which any effort to reduce the radiation exposure cannot be justified.

Most of the *protection schemes* depend upon *distance and barriers*.

The greater the distances, atomic number and thickness of the barrier, the smaller the exposure rate.

Barriers may be against primary radiations (here a greater thickness of the barrier is used) or secondary radiation (in this case the thickness or the barrier is less).

The most commonly used material as a barrier is **Lead**, this is because lead has:

- Higher atomic number.
- Higher density.
- Higher linear co-efficient of attenuation.

Lead can be used in form of:

- Viewing windows, that is glass into which lead is incorporated.
- As lead plywood that is lead sandwiched between layers of wood.

Before taking a radiographic exposure, it is necessary for both the operator as well the patient to become acquainted with the risks associated with ionizing radiation. It is also necessary for the operator to judge whether there is a justification for the radiograph being taken or the possibility of frequent treatment being done smoothly even without the radiograph.

Sources of Radiation in a Dental Radiology Department: (Fig. 6.2)

1. Primary beam is defined as radiation originating from the focal spot.
2. Scattered or secondary radiation is the radiation originating from the irradiated tissues of the patient.
3. Leakage or stray radiation is the radiation from the X-ray tube head housing.
4. Scattered radiation is the radiation from filters and cones.

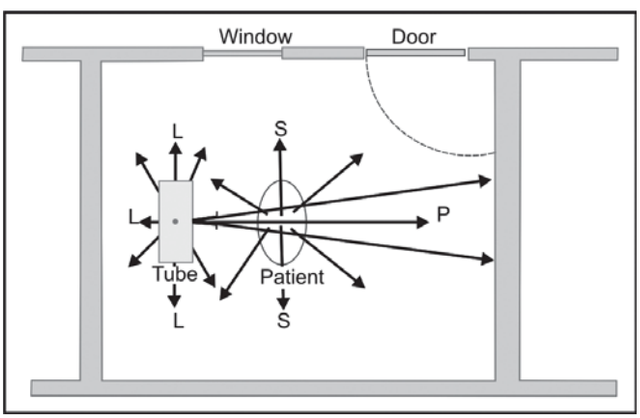


Fig. 6.2: Primary (P), Scattered (S) and Leakage (L) radiation during an X-ray exposure

5. Scattered radiation is the radiation coming from the objects other than the patient such as the walls and furnitures that the primary beam may strike.

The means of protection can be divided into:

A. Protection for the operator.
B. Protection for the patient.
C. Protection for and from the environment.

Protection for the Operator

The two most important sources of X-rays to which the operator is exposed to are the primary X-ray beam and scattered radiation originating from the irradiated tissues of the patient.

Other sources of lesser importance include:

- Leakage radiation through the tube head housing.
- Scattered X-ray from filters, cones.
- Scattered radiation coming from objects other than the patient, such as walls and furniture that the primary beam may strike.

Protection against primary beam:

[Primary beam: It is defined as radiation emitted by the focal spot of the target]

i. Effort must be made so that the operator can leave the room or take a suitable position behind a barrier or wall during exposure.
ii. Dental Operatory should be designed and constructed to meet the minimum shielding requirements.
iii. Position Distance Rule—which states that the operator should stand at least six feet away from the source of radiation or the operator should be at an angle of 90° to 135°, with respect to the direction of the central ray, (This rule takes advantage of the inverse square law to reduce the intensity and also considers that in this position the patient's head will absorb the most scattered radiation.) (Fig. 6.3) or

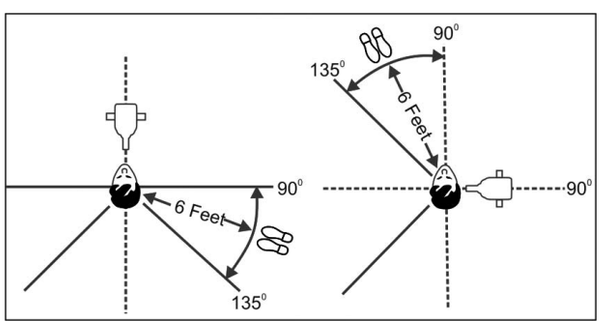


Fig. 6.3: Position and Distance Rule. If no barrier is available, the operator should stand at least 6 feet from the patient, at an angle of 90° to 135° to the central ray of the X-ray beam when the exposure is made

iv. Behind a barrier, made of suitable material, or
v. If there is no shield or barrier the operator should use a lead apron.
vi. The film should never be held by the operator. Ideally film holding devices should be used. If correct retention and placement is still not possible a parent or any other individual responsible for the patient must hold the film in position.
vii. There should be no use of fluorescent mirrors in the oral cavity at the time of exposure.
viii. Avoid holding the X-ray tube head of the machine. The suspension arms should be adequately maintained to prevent housing movement and drift.

Protection against leakage radiation:

[Leakage or Stray Radiation is defined as radiation emitted by any other part of the X-ray tube other than the focal spot].

i. Neither the tube housing nor the cone should be hand held during exposure.
ii. The machine should be periodically checked for leakage.

Protection from secondary and scattered radiation:

[Secondary radiation is defined as the radiation emitted by a substance through which X-rays are passing. Scattered radiation is defined as that radiation that has under gone change in direction during passage through a substance]

i. Use of high speed films.
ii. Replace the short plastic cone with an open ended lead lined cone.
iii. Adequate filtration of the primary beam.
iv. Use of collimator, to reduce the diameter of the beam.
v. Use of film badge/TLD badge/ Pocket Dosimeter, for personnel radiation monitoring, to avoid accumulated over exposure.

Protection for the Patient

Patient dose from dental radiography is usually reported as the amount of radiation received by target organs. One of the most common measurements is the skin or surface exposure. Other target organs commonly reported include the bone marrow, thyroid glands and gonads.

1. *Mean active bone marrow dose*: The dose derived as a specific dose relevant to a particular stochastic effect, leukemia. It is that dose of radiation that is averaged over the entire bone marrow.
2. *Thyroid dose*: The proximity of thyroid gland to the X-ray beam is of crucial important in determining the magnitude of dose received.

Particular concern has been expressed over the exposure of thyroid because it has one of the highest radiation induced cancer rates. Studies have reported that the dose to the gland from oral radiography is fairly low.

3. *Gonad dose*: Radiographs that involve the abdomen result in the highest dose to the gonads. As a general category the dental X-ray examinations result in a generally insignificant dose to the gonads.

The decision to use diagnostic radiography rest on professional judgment of its necessity for the benefit of the total health of the patient. Becoming aware of the potential risk associated with the use of ionizing radiation is the first step towards exposure and dose reduction in diagnostic radiography. Next is the use of the right techniques, materials and equipments that optimize the radiological process. It may be categorized as follows:

Patient selection: High yield or referral criteria, which is the clinical or historical findings that identify patients for whom a high probability exists that a radiographic examination will provide information affecting their treatment and prognosis.

Conduct of the examination: When the decision is made that a radiographic examination is justified, the way in which the examination is conducted greatly influences patient exposure to radiation. It is divided into:

i. *Selection of the Image Receptor:*
   a. Use of high speed films, which will help reduce the exposure time. Although the image quality may be compromised, E speed films are routinely used without loss of diagnostic information. (Table 6.5, Fig. 6.4)
   b. Use of screen films, the use of intensifying screens also helps reduce exposure time to the patient, but the diagnostic result of non screen films are far superior.

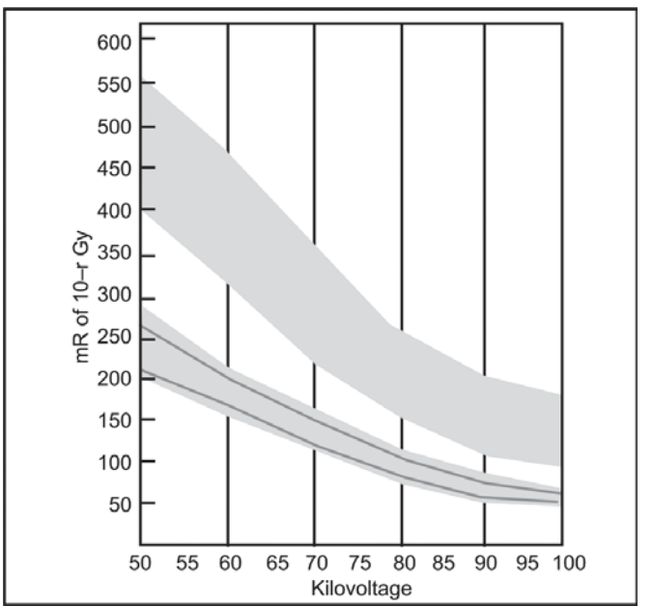


Fig. 6.4: Relationship of surface exposures delivered to a patient by exposure of group D, E and F (in light gray) intra oral films and diagnostic density at various kilovoltages

ii. *Use of Intensifying Screens:*
Here too there is a compromise on the image quality, in order to reduce exposure to the patient.

iii. *Focal Spot Film Distance:*
As X-rays are less divergent at a longer distance, there is a decrease in the volume of the patient exposed (Fig. 6.5). Longer FSFD results in 32% reduction in exposed tissue volume.

The use of longer FSFD also results in a smaller apparent focal spot size and thereby theoretically increases the resolution of the radiograph.

Source Skin Distance (SSD): As the SSD is increased, the collimation must be correspondingly increased to reduce the beam size, thereby reducing the volume of tissue irradiated, thus reducing patient dose.

Table 6.5: Milliampere-seconds required to expose speed group D and E intraoral radiographic film to diagnostic density at a focal spot-to-film distance (FSFD) of 16 inches

*Operating kilovoltage**	*Milliampere-seconds***					
	D			*E*		
	Low	*High*	*Mean*	*Low*	*High*	*Mean*
70	6.7	10.9	8.8	3.6	4.8	4.2
90	3.1	6.0	4.6	1.7	2.6	2.2

*Using a half wave-rectified X-ray machine with minimal HVL, as shown in Tables 6.3 to 6.5.
**For an 8-inch FSFD, divide by 4.

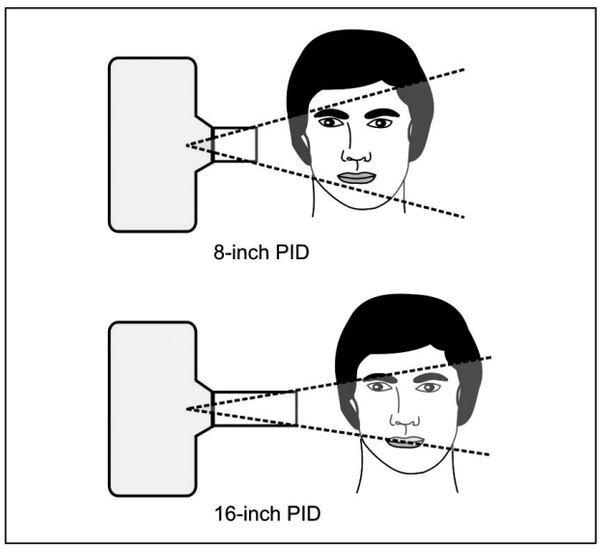


Fig. 6.5: Compared to the Short (8 inch) PID, the Longer (16 inch) PID, is preferred because it produces less divergence of the X-ray beam

The operating SSD depends on the kVp of the machine.

Equipment operating below 50 kVp should have a minimum distance of 10 cms (4") from the end of the PID to the focal spot.

Equipment operating above 50 kVp should have a minimum distance of 18 cms (7") from the end of the PID to the focal spot.

iv. *Collimation of the Beam*: Collimation helps to control the size and shape of the X-ray beam, allowing only the useful beam to emerge; (Useful beam is defined as that part of the primary radiation which is allowed to emerge through the collimating device).

In intra oral machines there are fixed collimators and in extra oral machines there are adjustable.

The beam should be limited to as small as an area possible for a particular radiographic examination. The recommended beam size is not more than 2 ¾" in diameter at the patient's face, when the source film distance is 18 cm or more (Fig. 6.6).

Collimation decreases the risk of radiation, minimises scattered radiation and decreases the fog, with a sharper image and better contrast (Fig. 6.7).

v. *Filtration*: Filtration preferentially absorb low energy photons which are undesirable as they add to the patient's skin dose but do not have enough energy to penetrate the tissue and bring about the image formation (Fig. 6.8).

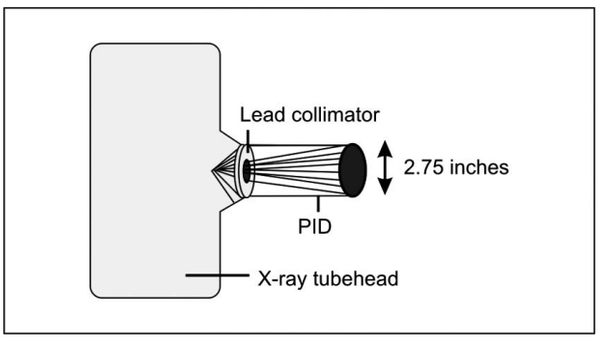


Fig. 6.6: The federal regulations (in USA) require that the diameter of a collimated X-ray beam be restricted to 2.75 inches at the patient's face

The amount of filtration should be in accordance with the machine's operating range;

Below 50 kVp;	0.3 to 0.5 mm of aluminum (half value layer)
50-70 kvp;	1.2-1.5 mm of aluminum
Above 70 kvp;	2.1-4.1 mm of aluminum

Rare earth materials like samariun, yttrium, niobium, etc. are also used in combination with aluminum filters, and help to reduce the patient exposure by 20%.

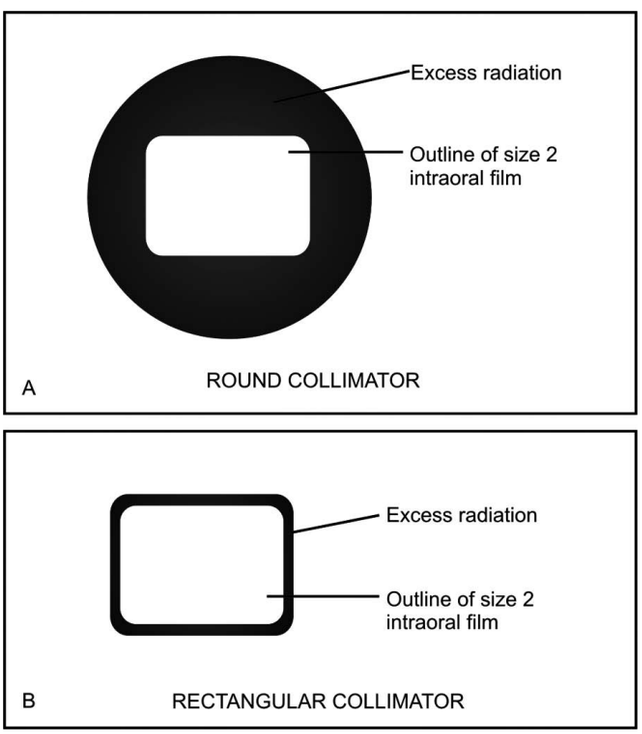


Fig. 6.7: A. The beam produced by a circular collimator is 2.75 inches in diameter, which is much larger than a size 2 intra oral film. **B.** The beam produced by a rectangular collimator is just slightly larger than a size 2 intra oral film

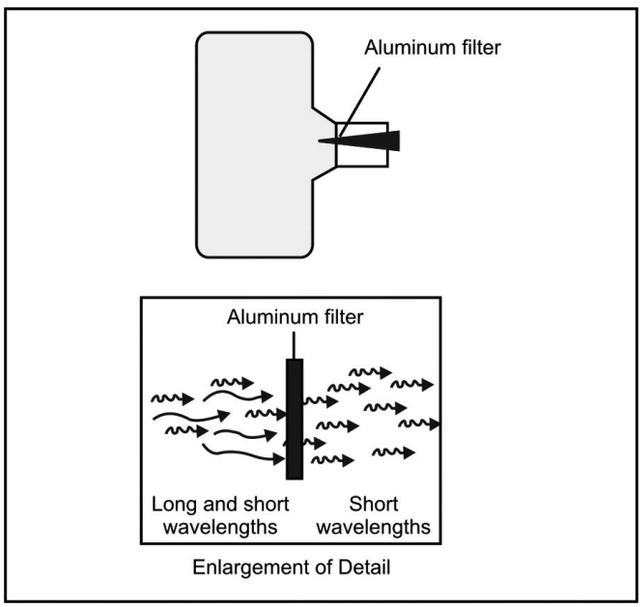


Fig. 6.8: The purpose of placing aluminum disks in the path of the beam is to filter out the low energy, long wave lengths that are harmful to the patient

The disadvantage of using filters is that it leads to an increase in the exposure time and a decrease in the contrast.

vi. *Use of high kVp*:
Higher kVp is used to keep the incident skin doses acceptable. The equipment should be capable of operating at a kilo voltage of 60 kVp or higher.

vii. *Use of positioning indicating devices*:
These help to minimize the volume of tissue irradiated in intra oral radiography, it is necessary to increase the target film distance by using longer position indicating devices to direct the X-ray beam.

One of the most widely used PID is the long open ended cylinder. This instrument reduces the more divergent rays that are inherent in the use of the short target film distance. As a result the diagnostic quality of the image is markedly improved and significantly smaller doses of radiation are delivered to the head and neck, this is due to the reduction of the beam divergence and concomitant reduction of the scattered radiation (Fig. 6.9).

If a change is made in the technique from short cone to long cone, it is important to simultaneously reduce the size of the collimator aperture.

The use of open ended cylinders instead of a pointed plastic cone further reduces the scattered radiation that occurs when the X-ray beam passes through the plastic cone (Fig. 6.10).

viii. *Film holding devices*:
These offer protection to the patient, because
- their use often reduces frequency of retakes, as the film can be positioned more accurately in the patient's mouth.
- they also provide an external guide to indicate the film position.
- The possibility of misaligning the X-ray tube and partially missing the film (cone cut), is also reduced.
- Some of the holders also collimate the beam to the size of the film being used, which further reduces patient exposure.

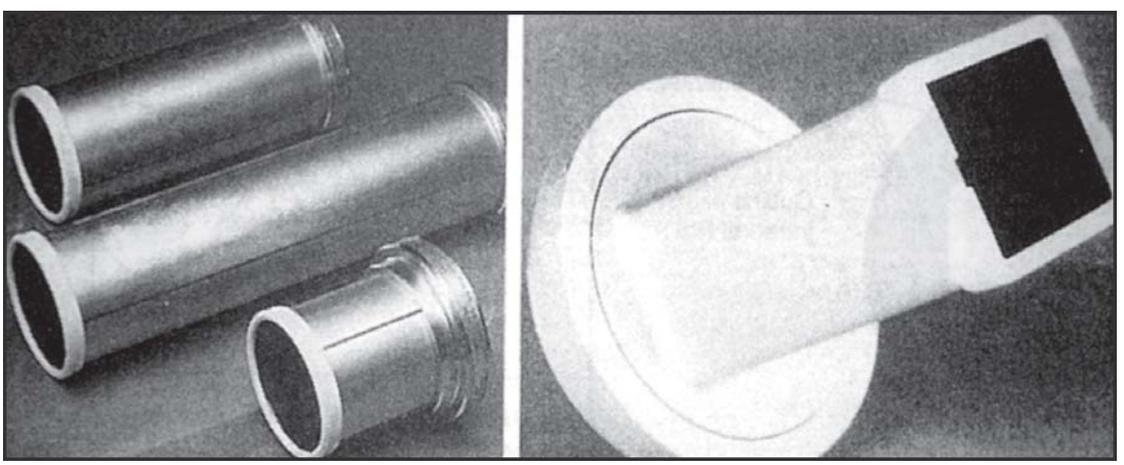


Fig. 6.9: A. Open ended, lead lined PIDs do not produce scatter radiation. **B.** Open ended, lead lined rectangular PID

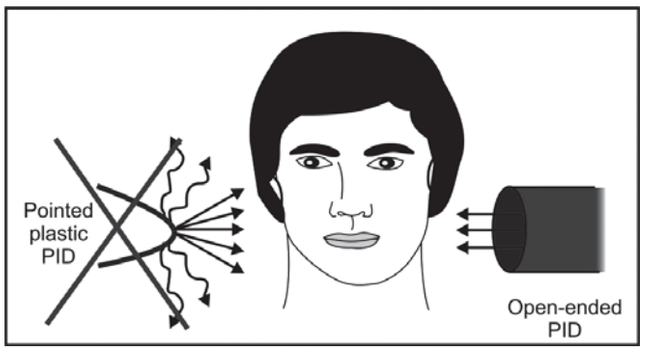


Fig. 6.10: A plastic pointed PID produces scatter radiation and should be replaced by the open ended lead lined PID

– The exposure to the patient's fingers is also reduced, as the patient does not have to hold the film.

ix. *Timers*

Most equipment are provided with 'dead man' timers. This timer requires a continuous pressure on the button (switch) during the exposure cycle in order to continue the operation of the X-ray machine. If the button is released the exposure is terminated.

Dental X-ray machine timers generally automatically reset once the exposure has been terminated. Care should be taken that they are not capable of initiating another exposure until the switch is pressed again. Also, it should not make an exposure if the timer is set to zero or off position.

The X-ray timer should be accurate (it should deliver the time exposure for which it is set) and reproducible (it should repeatedly deliver the same time interval at a given setting).

The use of the electronic or synchronized timer permits exposure as low as 1/20 to 1/30 seconds, which was not possible with the traditional mechanical timer.

x. *Use of Protective Barriers:*

a. Leaded aprons should be used to protect the patient, especially in case of children, individuals of reproductive age and pregnant women. The lead apron provide more protective benefit to the males (Fig. 6.11).

When used the lead apron should have a protective equivalent of 1/4th mm of lead.

It should be remembered that the lead aprons are a secondary measure to protect the patient and should not be substituted for use of fast films, lead collimation and aluminum filtration, which are the primary means of reducing exposure to the patient.

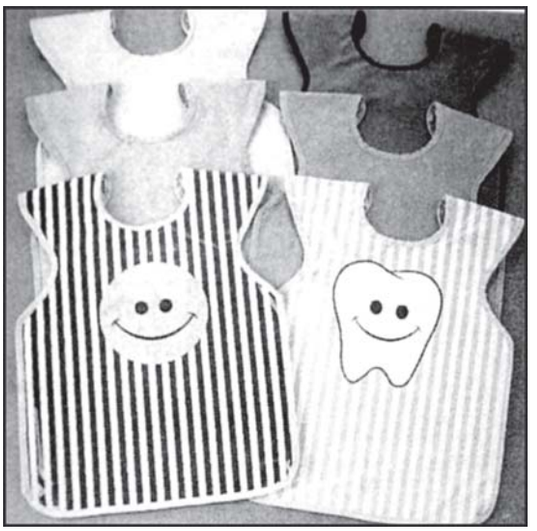


Fig. 6.11: Lead aprons

b. Use of gonadal shields.

c. Use of leaded thyroid shields, this is recommended especially when cephalometric examinations are carried out on children because of greater sensitivity of thyroid in young people (Fig. 6.12).

d. Use of film holders with facial shields.

xi. *Use of proper technique:*

The use of proper technique for the imaging of the particular anatomy of the patient.

xii. *Processing the image*:

If films are not processed properly, retakes are required, increasing patient exposure and cost.

xiii. *Interpretation of the image*:

The radiograph should be viewed under proper conditions with an illuminated viewer. Proper interpretation precludes the necessity of retaking the images and subjecting the patient to additional exposure.

Fig. 6.12: A thyroid collar

Protection of the Environment

The surrounding environment must be protected from radiation to avoid exposure to persons in the environment.

i. Primary beam should never be directed at any one other than the patient.

ii. Patient should be positioned such that the X-ray beam is aimed at the wall of the room and not through a door or other opening where people may be located.

iii. Walls made of 3″ of concrete, 3″ × 16″ of steel or 1 mm of lead will suffice to protect adjacent rooms, even if the work load in the radiology department is high.

An alternative to lead is barium due to it's high atomic number, high density and high linear co-efficient of attenuation. Barium can be used in the form of Barium Plaster or Barium Concrete.

If it is not possible to incorporate lead or barium into the walls, they can be lined with lead plywood, 0.25 mm of lead sandwiched between layers of wood.

Primary barrier should be incorporated in any part of the floor or ceiling of the room at which the beam is fired (Fig. 6.13).

Secondary barrier in the walls, provide protection against scattered or leakage radiation and as exposure rates are small they are ½ the thickness of the primary wall.

iv. Windows: It is necessary for the operator to see the patient as he is being irradiated, so a window is provided. This window should be situated such that the primary beam is not directed on it. Lead glass should be used (Fig. 6.14).

v. Doors of the radiology room should function as secondary barriers. They may have lead incorporated in them. Switches may be incorporated so that the beam is cut off as soon as the door is opened and not allow the beam to be switched on till the door is closed completely (Fig. 6.15).

vi. Quality assurance may be defined as any planned activity to ensure that a dental office will consistently produce high quality images with the minimum exposure to patients and personnel.

vii. *Continuing education*: Practitioners should stay informed of new information on radiation safety issues as well as developments in equipment, materials and techniques and adopt appropriate items to improve radiographic practice.

viii. Regular radiation surveys, should be performed at regular intervals as the amount of exposure is dependent on many factors, such as:

a. the machine's kilo voltage.

b. the work load of the X-ray machine

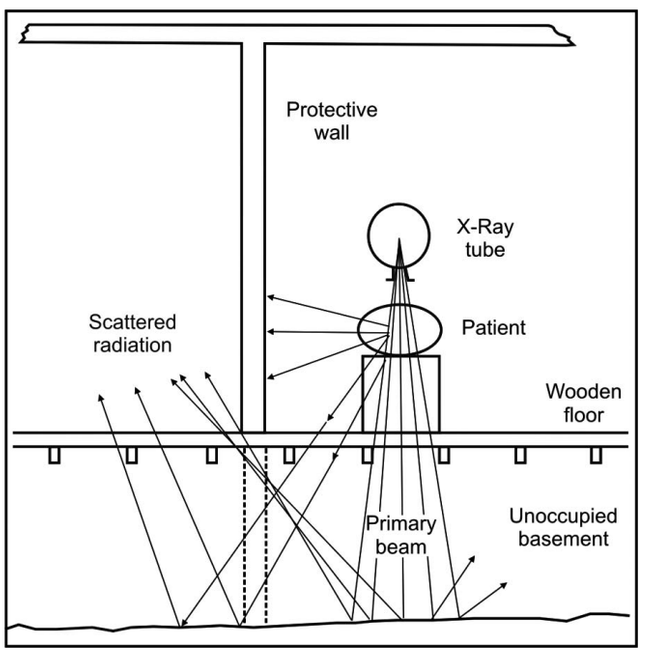


Fig. 6.13: Radiation may be scattered in a floor or space beneath, and reach adjoining rooms as shown. To prevent this the protective wall be taken below floor level as indicated by the dotted line, or protective material can be incorporated in the floor

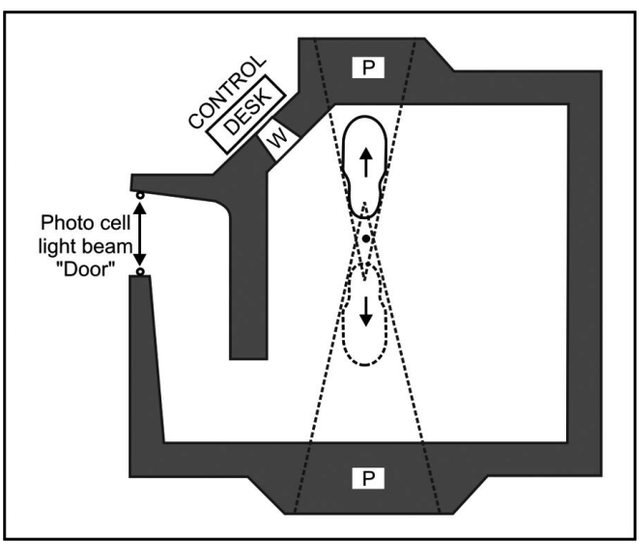


Fig. 6.14: Plan of room suitable for mega voltage X-ray unit. The 'maze' entrance will be noted and the position of the light beam, interruption of which cuts off any treatment in progress. Note that the viewing window cannot receive the primary beam. It need only be a secondary barrier. W-window, P-primary barrier

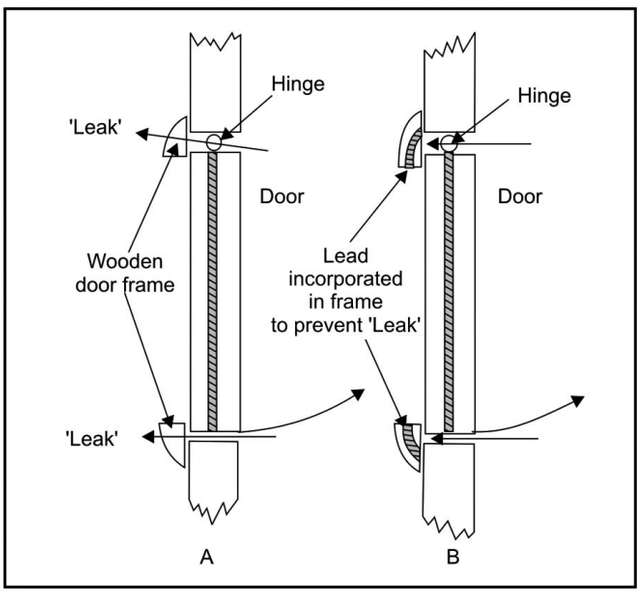


Fig. 6.15: Radiation may leak through the inevitiable spaces around a fully protected door set in a full protection wall, as shown in **A**. To prevent this overlapping protective material must be included, as shown in **B**

c. the X-ray absorbing ability of the walls (by using radiation measuring device).
d. the amount of time the adjacent areas are occupied by people.

vi. Radiation monitoring is measuring of the X-ray exposure of operators or associated personnel as a protective measure. There are various monitoring devices available.

For the Department

I. Electrical
   Ionization Chamber
   Thimble Chamber
   Proportional Counter
   Geiger Counter
II. Chemical
   Film
   Chemical Dosimeter
III. Light
   Scintillation Counter
   Gerenkov Counter
IV. Thermoluminescence
   Thermoluminescent Dosimeter
V. Heat
   Calorimeter

Ionizing chamber (Figs 6.16 and 6.17): This consists of a pair of collecting plates each with an opposite charge separated by a standard volume of air. The plates are connected by a electrometer (a sensitive galvanometer) capable of measuring a small electrical charge. Prior to use a standard charge is applied to the two plates.

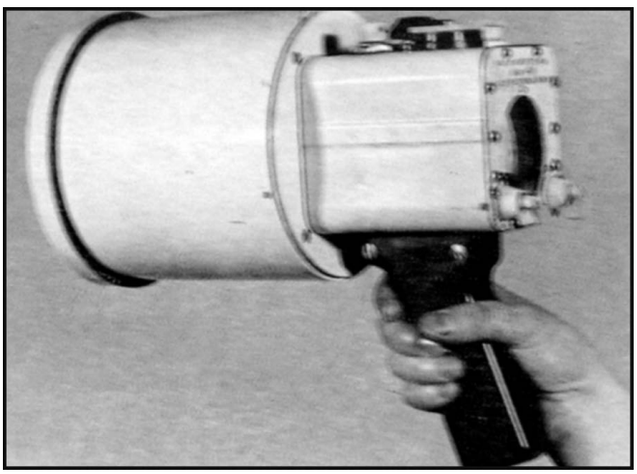


Fig. 6.16: A Typical Radiation Survey Meter. This has an ionizing chamber with a volume of about 800 ml, and a robust and fairly sensitive, battery operated amplifier, which presents the exposure rate as a reading on a meter. On the most sensitive range the full scale reading of this sort of instrument will be about 3mR per hour

When an X-ray beam is directed through the air in the chamber, ion pairs (electrons and their associated positively charged atoms) are generated by interaction of X-ray photons with air molecules. The positive and negative ions produced by radiation will be attracted to the plates of opposite charge and cause a partial discharge. The magnitude of the X-ray exposure is thus a function of the number of ions produced and is measured by the magnitude of the drop in potential between the collecting plates of the galvanometer.

Thimble chamber (Fig. 6.18): It consists of a small thimble shaped ionization chamber filled with an inert gas – argon.

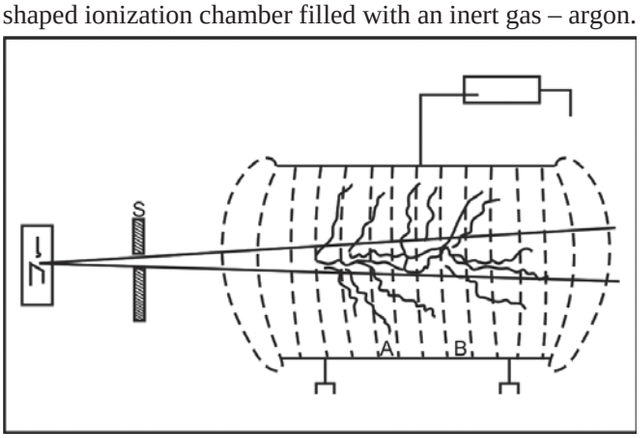


Fig. 6.17: Ionization chamber

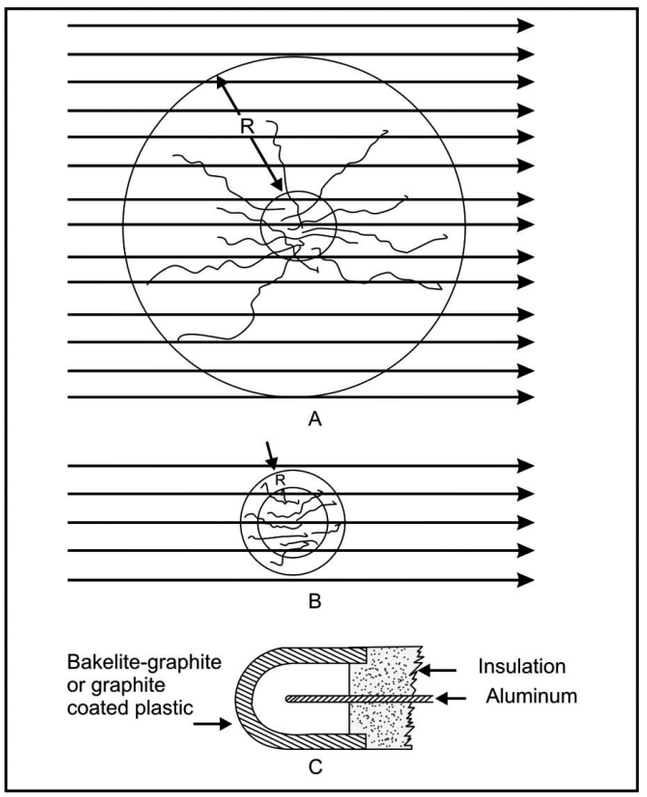


Fig. 6.18: The development of the thimble ionization chamber. **A.** Ionization in air, **B.** The solid air wall, **C.** The thimble chamber

A positively charged metal plate is placed in the center and the walls are negatively charged and based on the extent of ionization of the air within the chamber when an X-ray beam is incident on it, the X-ray exposure is determined.

Advantages of Ionizing Chambers (e.g. Thimble Chamber)

- Most accurate method of measuring radiation dose.
- Direct read out gives immediate information.

Disadvantages of Ionizing chambers (eg. Thimble Chamber)

- They give no permanent record of exposure.
- No indication of the type of energy of the radiation.
- Personal ionization monitors are not sensitive to low energy radiation.
- They are fragile and easily damaged.

Rate meter: It has an ion collecting chamber that is continually being charged by a battery. This instrument constantly measures the amount of ionization taking place in the air within the chamber.

Geiger counter (Fig. 6.19): This works on the principle of 'ionization by collision'. It is used to detect and record much smaller amounts of ionization than the ionization and thimble chamber, e.g. ionization caused by radioactive atom decay.

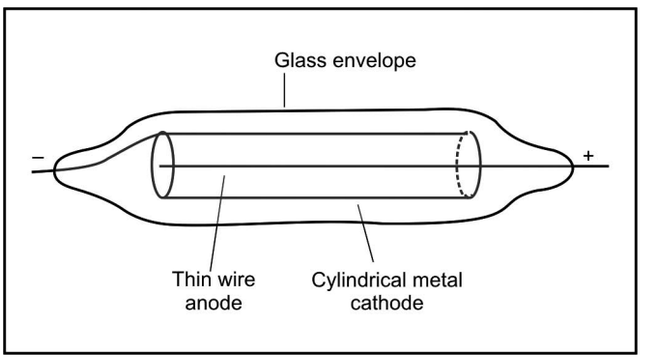


Fig. 6.19: The basic design of a Geiger-Muller counter

This counter is also unable to discriminate between different radiations or different energies of the same radiation.

Scintillation Counter (Figs 6.20 and 6.21): X-rays are incident on a phosphorescence substance which releases visible light proportional to the amount of X-ray incident on it and this is reflected by a system of angulated mirrors which amplifies it. This light when it leaves the chamber gives rise to an impulse. The number of impulses generated are proportional to the amount of X-rays incident on the chamber.

Potentiometer: A potentiometer, using aluminum can be used to determine the amount of radiation exposure.

Personal Monitoring Devices

Pocket Dosimeter
Film Badge
Thermoluminescent Dosimeter (TLD)
Electronic Dosimeter

Pocket dosimeter (Fig. 6.22): The pocket dosimeter or chamber is about the size of a fountain pen and has a clip for fastening in a pocket. This is a reliable means of measuring day to day exposure of people working with sources of radiation. There are two types of pocket dosimeters, both work on the principle of 'air wall' ionization chamber and is based on the operational definition of the roentgen.

The first type known as the Minometer or the Condensor type or the indirect reading type. It is an ion chamber which has a voltage potential placed on it by insertion into a charger. Radiation penetrating the chamber causes the current to leak off in proportion to the radiation exposure. By reinserting the dosimeter into the charge reader at the end of the day, the resulting voltage drop is calibrated in milliroentgen. Usually two dosimeters are worn at a time with the lower of the two readings taken as more accurate. It is necessary to recharge the Indirect Reading Pocket Dosimeters after every reading.

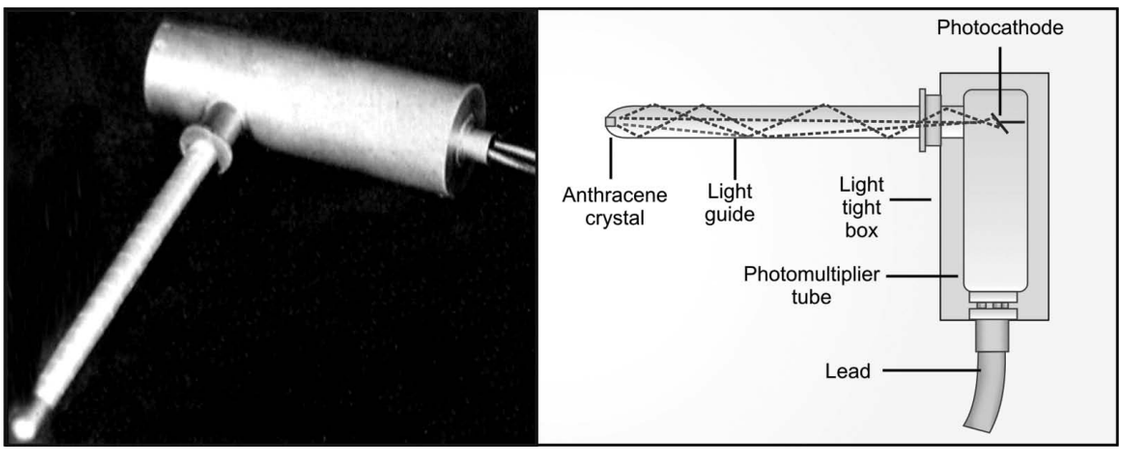


Fig. 6.20: A Scintillation counter for measurements inside body cavitied. The dotted lines indicate the reflection of light along the internally polished guide on to the photo cathode

The second type is the Direct Reading Dosimeter which operates on the principle of the Gold Leaf Electroscope. A quartz fiber is displaced electro statically by charging it to a potential of 200V. An image of the fiber is focused on a scale and is viewed through a lens at one end of the instrument. Exposure of the dosimeter to radiation discharges the fiber, allowing it to return to the original position.

Pocket dosimeters are also suitable for area monitoring work in which case chambers of larger volumes are used.

Film badges (Figs 6.23 and 6.24A): The phenomenon that X-rays blacken photographic films is applied here.

The blackening of a plain film does not alone give a reliable indication of the exposure to which the film has been subjected. If, however, the film is 'sandwiched' between two thin sheets of tin each about 1mm thick, the blackening per unit exposure is much more uniform over a wide range of radiation energies. The tin has practically no effect on the high energy radiation, thus the blackening per unit exposure is practically unaffected by the presence of the tin. However, the low energy radiation is considerably attenuated by the tin, so that the blackening it produces is reduced.

The degree of blackening produced on the film by the radiation is measured by a 'densitometer' and when adequately caliberated, it gives the amount of radiation to which the wearer has been exposed.

In each badge there is a part of the film which is not covered by any filter. This 'open' part of the system has an important role. Taking a simpler badge as an example, the ratio of the blackening (fog) in the open part of the film to

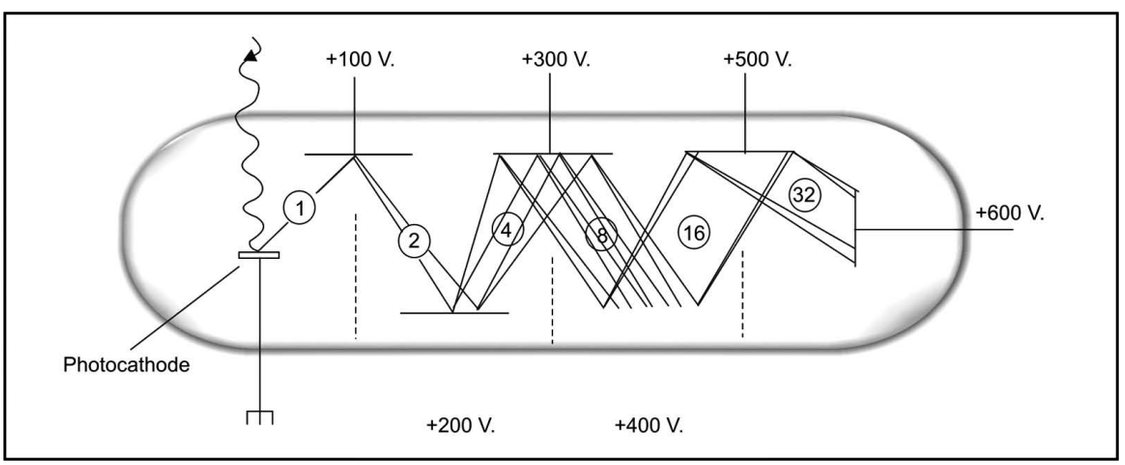


Fig. 6.21: The principle of operation of a photomultiplier tube. The numbers in the circles indicate the amplification being produced at each stage of this example

Fig. 6.22: Pocket dosimeter

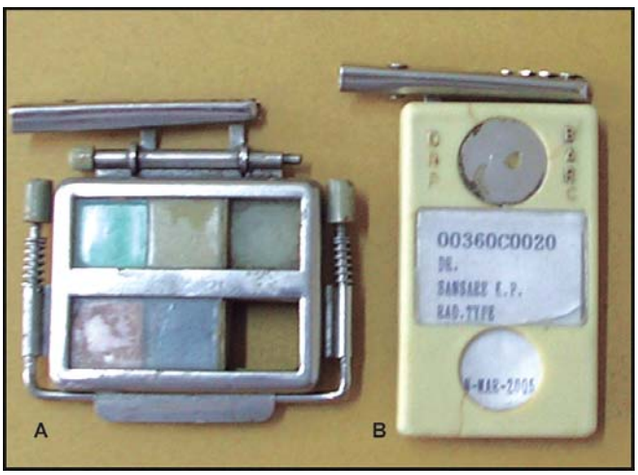


Fig. 6.24: A. Film Badge. **B.** TLD Badge

that of the region under the tin filter gives an indication of the quality of radiation to which the badge has been exposed.

If both portions are almost equally blackened, 'hard' gamma rays or high energy X-rays would be the likely cause.

If the blackening in the open part is four times as great as that under the tin, then low energy X-rays may have been involved.

The film badge uses a dental film enclosed in a light tight cover in a metal framework containing various filters. The badge usually has 6 quadrants:

- Open
- Aluminum
- Cadium
- Cuprous
- Cupric
- Lead

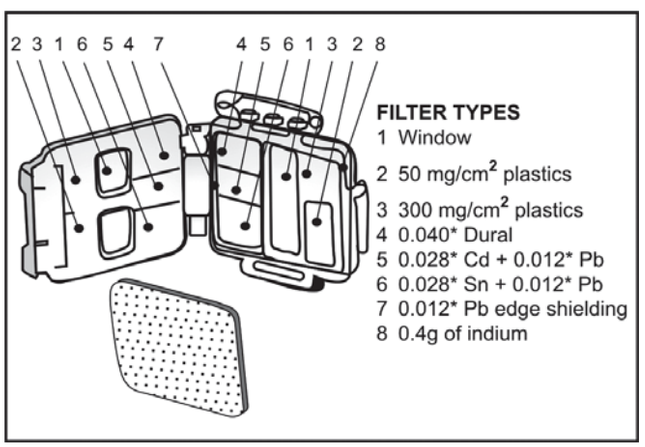


Fig. 6.23: Film badge, showing various filters used

The ratio of blackening of the open part of the film to that produced in regions of filters gives an indication of the quality of radiation to which the wearer has been exposed.

Advantages

1. Good for measuring any type and energy of radiation. e.g. X-rays, gamma radiations.
2. Continuous assessement is possible.
3. Accumulated dose can be calculated.
4. Provides a permanent record of dose received.
5. Simple, robust and relatively inexpensive.

Disadvantages

1. Accuracy is only 10 to 50%, as many low energy photons may not penetrate the film.
2. Range of exposure is less.
3. The results are dependent on the processing, the strength and type of developer used and the speed of the film used, and may lead to errors.
4. No immediate indication of exposure- all information is retrospective.
5. The darkening of the film is not necessarily linear to the dose, due the presence of scattered radiations.
6. The film may also be affected by visible light.
   - Wearing of the badge
   - The badge is usually monitored every 2 weeks, or sometimes in 4 weeks, in cases where it is certain that the radiation hazard is very small.
   - Should accidental high exposure be suspected, the film should be immediately processed.

- Badges are normally worn at the chest or waist level on the outside of the normal working clothes, to give an indication of the whole body exposure to which the work is subjected.
- If lead rubber gloves or a protective lead apron is worn, the badge should be underneath the apron, since it is the exposure to the worker's body and not to the apron that is of interest.
- Modified versions of the badge are also available to be worn on the wrist, to indicate general hand exposure and on the forehead to provide an estimate of the exposures to the eyes.

7. Badges are prone to filter loss.

A recent development in the film badge dosimetry is the Twin Film Service. The subscriber receives a clip on film pack holder containing two separate film packs. One used for weekly dose determination. The customer keeps the same film holder for a 13 week period and is supplied with a new slide-in film pack of a different color each week. At the end of the week, the used weekly packets are mailed to the service company laboratory. The films, sensitive to alpha, beta and gamma radiations are developed and compared in precision densitometers with films exposed to accurately determined amounts of radiation.

The Thermoluminescence Dosimeter (TLD) (Figs 6.24B and 6.25). This is used for measurements of the actual dose received by the operator /patient as a result of radiography or radiotherapy exposures and are the most common type of personnel monitoring devices used. Since the amount of material and therefore the size is small and it also causes nearly the same attenuation of the X-ray beam as does soft tissue, the TLD can very easily be placed on the skin or in the body cavity during exposure.

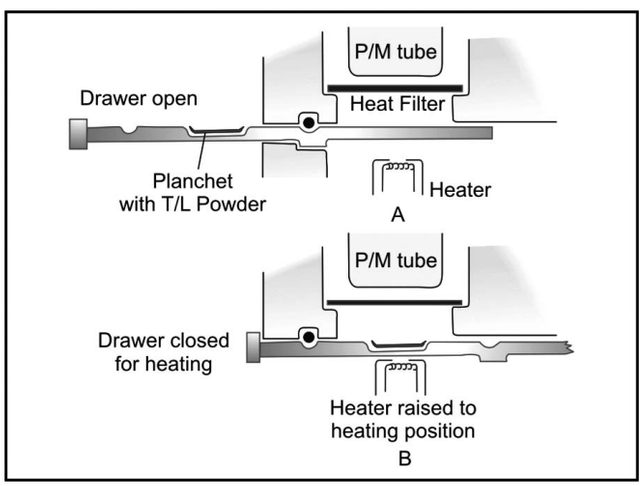


Fig. 6.25: The drawer and heater arrangement in a thermoluminescence dosimeter

The TLD badge in India, consists of a TLD card holder cassette of high impact plastic. The TLD card consists of a Nickel plated aluminum plate having 3 symmetrical holes, each of diameter 12 mm, over which 3 identical $CaSO_4$ embedded Teflon disks are dipped (13.2 mm diameter, 0.8 mm thickness, 280 mg weight). These disks are clipped on an aluminum card loaded in the cassette having three filters:

1. Open region.
2. Copper.
3. Aluminum.

Thermoluminescence is the property of a substance (e.g. Lithium fluoride) to emit light or energy which it has stored when it is heated.

Principle of TLD badge: When the phosphor is irradiated, the X-ray energy is absorbed and secondary electrons are produced.

The secondary electrons causes holes in the filled zone by lifting the electrons to the conduction band.

These fall back into traps in a meta-stable states, where they are held.

When the phosphor is heated, to 200°-300°C, the trapped acquire energy to escape back to the conduction band.

From the conduction band they fall back to fill holes in the filled zone, and when they recombine, visible light is produced called "Thermoluminescence".

This thermoluminescence is proportional to the dose received by the operator during irradiation.

The TLD reader: The equipment used to heat the exposed material and measure the emitted light is called the TLD reader. The reading given by this equipment is used as a measure of the absorbed dose to which the material was subjected. The reader comprises of 3 main parts:

1. Heater.
2. Photomultiplier tube.
3. Electronic system.

Glow curve: (Fig. 6.26): There is a variation of intensity of light emitted as the TLD material is heated up from room temperature to 300°C.

Quite a lot of light is emmited at temperatures below 150-200°C.—'A'.

However, if the irradiated material is stored at room temperature before 'read-out' it is found that the glow curve changes to 'B'.

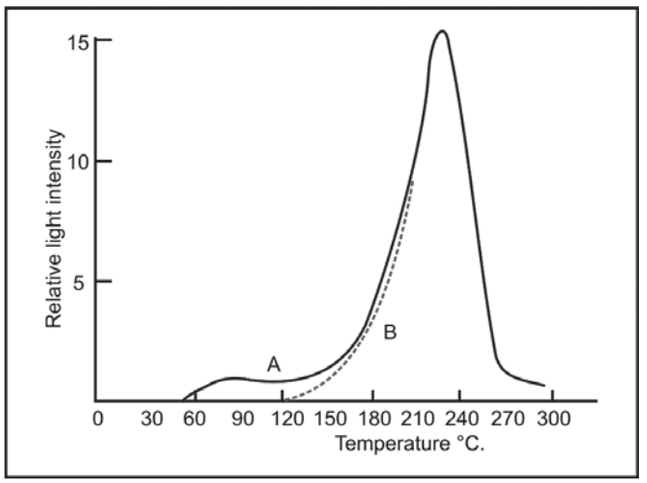


Fig. 6.26: A thermoluminescence 'glow curve'. **A.** Produced shortly after the material was irradiated. **B.** Produced after storage of about a day

This is due to leakage electrons stored in more shallow traps during storage.

Majority of this 'fading' occurs in the initial 24 hours after which response is fairly constant.

This ability to store the signal and permit read-out at a later date is a very useful property of the TLD material.

Wearing of the badge: The chest badge has a metallic clip and should be worn outside the working clothes and below the lead apron. Wrist badges have a snap for attachment. The badge has to be monitored every two months for radiation exposure.

Application: Radiotherapy- for measuring doses received by patients while actually undergoing the treatment exposures.

Radio diagnosis- with the increasing importance being placed on minimum dose received during radiography. TLD is assuming an important role.

Personnel monitoring- The ability of the TLD material to store dose over long periods of times makes it very suitable for use as an alternative to photographic film for personnel measurement.

Advantages

- Small in size and light in weight.
- Chemically inert.
- Almost tissue equivalent, i.e. response similar to human tissue, as LiF has a low atomic weight.
- Usable over a wide range of radiation qualities.
- Usable over a wide range of dose values.
- Sensitivity independent of dose rate.
- Accurate and reproducible readings.
- Automation compatible.
- No wet chemistry required.
- Reusable. By employing proper annealing the TLD can be reused a number of times.
- Economical. Reusability, generally reduces the cost per reading.
- Read out simple and quick.
- Apart from initial fading, can store dose over long period of time.
- Exposures can make 'in the field' away from the measuring laboratory.

Disadvantage

Read out is destructive, giving no permanant record, results cannot be checked or reassessed.

- Only limited information provided on the type of energy of the radiation.
- Dose gradients are not detectable.
- Relatively expensive.

The Electronic Dosimeter: This is five to two hundred times more sensitive than a TLD, with an audible alarm system.

BIBLIOGRAPHY

1. Allan B Reskin. Advances in oral radiology, PSG Publishing Co. 1980.
2. Barr JH, Stephens RG. Radiological Health. Dental radiology. Pertinent Basic Concepts and their Applications in Clinical Practise. Philadelphia, WB Saunders, 1980; 66-80.
3. Bushong SC. Radiologic Science for Technologist, Physics, Biology and Protection, 7th ed, St. Louis, 2001, Mosby.
4. Dowd SB, Tilson ER. Practical Radiation Protection and Applied Radiology, 2nd ed, Philadelphia, 1999, WB Saunder.
5. Frommer HH. Radiation Protection. Radiology for Dental Auxillaries, 6th edition St. Louis, Mosby- year book, 1996; 67-87.
6. Goaz PW, White SC. Health Physics. In Oral Radiology. Principles and interpretation, 3rd ed. St. Louis, Mosby- year book, 1994; 47-68
7. Hall EJ. Radiobiology for the Radiologist, 5th Ed. Baltimore, Zero Lippincott, William and Wilker.
8. Johnson ON, McNally MA. Essay C.E. Radiation Protection, inessentials of dental radiography for dental assistants and hygienists, 6th ed. Norwalk, Appleton and Lange, 199;105-30.
9. Mason-Hing LR. Fundamentals of Dental Radiography, 3rd ed., Philadelphia, WB Saunders, 1993; 221-29.
10. Meredith WJ. Fundamental Physics of Radiology, 2nd ed., 1972, John Wright and Sons Ltd.

Section Four
Imaging Principles

7

Ideal Radiograph

An Ideal Radiograph is one that provides a great deal of information, the image exhibits proper density and contrast, have sharp outlines and are of the same shape and size as the object being radiographed.

Or in HM Worth's words; "An Ideal Radiograph is one which has desired density and overall blackness and which shows the part completely without distortion with maximum details and has the right amount of contrast to make the details fully apparent".

It is important to remember that an image on the radiograph is a two dimensional representation of a three dimensional object. Therefore, to obtain maximum value from the radiograph, the clinician must mentally reconstruct an accurate three dimensional image of the anatomical structures of interest from the radiograph.

Two terms are used to describe the black and white areas viewed on the dental radiograph: *radiolucent* and *radiopaque*.

Radiolucent refers to that portion of a processed radiograph that is dark or black. A structure that appears radiolucent on a radiograph lacks density and permits the passage of the X-ray beam with little or no resistance, e.g. air space, pulp tissue.

Radiopaque refers to that portion of the radiograph that appears light or white. Radiopaque structures are dense and absorb or resist the passage of the X-ray beam, e.g. enamel, dentin and bone.

The characteristics of an Ideal Radiograph are:

A. Visual characteristic:
   i. Density.
   ii. Contrast.
B. Geometric characteristics:
   iii. Sharpness or detail, resolution or definition.
   iv. Magnification.
   v. Distortion.
C. Anatomical accuracy of radiographic images.
D. Adequate coverage of the anatomic region of interest.

i. *Density*: is the overall blackness or darkness of a dental radiograph.

When a radiograph is viewed against a light source, the relative transparency of areas on the radiograph depends on the distribution of black silver particles in the emulsion. Darker areas represent heavier deposits of black silver particles. Density is this degree of silver blackening.

If the density is too dark, the film will appear too dark and the resulting images cannot be visually separated from each other. A radiograph with correct density enables the radiographer to view black areas (air spaces), white areas (enamel, dentin and bone) and gray areas (soft tissue).

Factors Effecting the Density of a Radiograph

First Degree Factors

a. *Milliamperage (mA)*: An increase in milliamperage produces more X-rays that expose the film and as a result increase film density.

If mA increases then film density increases.

If mA decreases then film density decreases.

Thus density varies directly and proportionately as the milliamperage or the tube current.

b. *Exposure time*: An increase in the exposure time will increase the total number of X-rays that reach the film surface, thus the film density is increased.

If exposure time is increased, then film density is increased.

If exposure time is decreased, then film density is decreased.

Exposure time and milliamperage are interchangeable and are thus considered as a single factor – mAs.

c. *Operating kilo voltage peak (kVp)*: An increase in the kVp increases the energy of the X-rays, hence increases their power of penetration there by increasing the film density.

If kVp increases, then film density increases.

If kVp decreases, then film density decreases.

Thus density varies directly and in proportion to the square of the relative kVp.

$D \alpha (kVp)^2$

[A Thumb Rule states that an increase in 10 kVp doubles the output of the machine]

d. *Source film distance*: Since the intensity of an X-ray beam varies inversely as the square of the (S-F) distance, density also varies inversely as the square of the (S-F) distance.

$$\text{Hence Density} = \frac{(kVp)^2 \times mA \times S}{[(S\text{-}F)\ \text{distance}]^2}$$

Second Degree Factors

a. *Subject thickness*: Fewer X-rays will reach the film in a patient with an increased amount of soft tissue or thick dense bones. As a result the radiograph will appear light and have less density.

If subject thickness increases, then density decreases.

If subject thickness decreases, then density increases.

Adjustments in the operating mA, kVp or exposure time can be made to compensate for variations in size of the patient and subject thickness;

In case of a suspected pathology—

- If destruction is suspected then exposure time is decreased.
- If deposition is suspected then exposure time is increased.

In case of fair skinned individuals, they have increased circulation of blood per unit area of skin.

Blood contains calcium ions and therefore exposure time should be increased when radiographing these individuals, and a lower kVp and/or mA setting should be used.

Obese patients, have increased fat deposition and therefore exposure time should be increased when radiographing these patients, and a higher kVp and/or mA setting should be used.

If patient is small and has a narrow facial bone structure, the next lower kVp and/or mA should be used.

If the patient is edentulous, use the next lower kVp and /or mA setting.

b. *Development conditions*: The radiograph may be light or dark depending on whether the films are under or over developed.

c. *Type of film*:

- *Film speed*: High speed films require less mAs in order to obtain a density change.
- *Film latitude*: It is measured as a range of exposures that can be recorded as distinguishable densities on a film.
- *Radiographic noise*: It is the appearance of uneven density of a uniformly exposed radiographic film. It is seen on a small area of film as localized variations in density. The primary cause is radiographic mottle.

d. *Screens*: Use of screens require less mAs in order to obtain a density change.

e. *Grids*: The use of grids require more mAs in order to obtain a density change.

f. *Amount of filtration used*: Reduction in the amount of added filtration used will increase the number of photons reaching the film and hence increase the density.

g. *Fog*: Film fog may result in an undesirable form of darkening of the film.

Degree of Desired Density

It is usually considered a matter of individual preference, in case of a dental radiograph considered to be having the correct density, the dentist should be able to see a faint outline of the soft tissues in edentulous spaces or distal to the third molar teeth when the radiograph is viewed under routine conditions.

$$\text{Optical density} = \log_{10} \frac{Io}{I_t}$$

Where Io is the Intensity of Incident Light (e.g. from the view box)

I_t is the Intensity of light transmitted by the film.

When D = 0, 100% light is transmitted.

D = 1, 10% light is transmitted.

D = 2, 1% light is transmitted.

In routine radiographs, the useful range of film density is approximately 0.3 (very light) to 2 (very dark).

Beyond these limits, the image is not of any diagnostic value.

Characteristic Curve (Fig. 7.1)

A graphic plot of relationship between film density and exposure is called a Characteristic Curve or H and D Curve after Hurter and Driffield who first described this relationship in 1890.

This curve is typical of a screen-film combination, and reveals information about film contrast, speed and latitude. It can be seen from the curve that:

- As exposure is increased, density also increases.
- The film has greatest diagnostic value, at the relatively straight portion of the graph, that is between 0.6 and 3, optical density units.

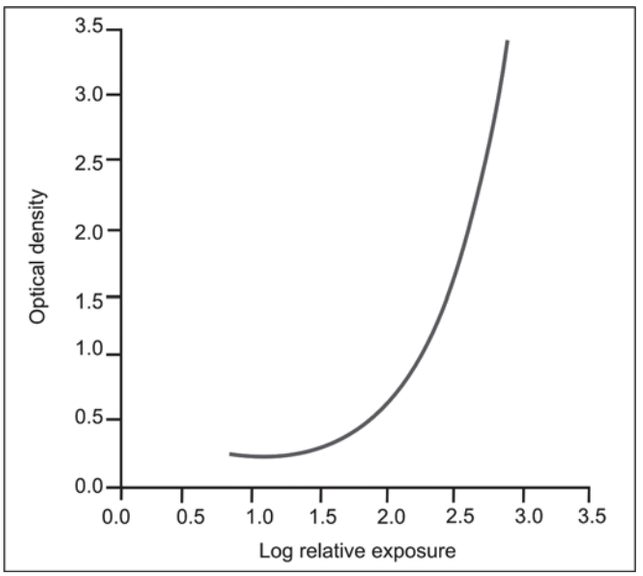


Fig. 7.1: Characteristic curve of direct exposure film. The contrast (slope of the curve) is greater in the high density region than in the low density region

ii. *Contrast*: is the difference in the degree of blackness (densities) between adjacent areas on a dental radiograph.

If a dental radiograph has very dark areas and very light areas, it is said to have a 'high contrast', as the dark and the light areas are strikingly different.

A radiograph that does not have very dark and very light areas, but instead has many shades of gray is said to have a 'low contrast'.

In dental radiography a film that is a compromise between low and high contrast is preferred.

The overall contrast of a dental radiograph is determined by film properties or film contrast and the object radiographed or the subject contrast:

a. *Film contrast*: This refers to the characteristics of the film that influence the radiographic contrast. These characteristics include:
   - *Inherent qualities of a film*: These are under the control of the film manufacturer and cannot be changed by the dental radiographer.
     – Fast film requires less exposure but give decreased contrast and sharpness.
     – Double coated film with less exposure produce decreased contrast.
     – Films with thicker layer of emulsion, require more developing time and give increased contrast.
   - *Film processing*: This process is under the control of the dental radiographer.
     – Increase in the developing time will give increased contrast.
     – Increase in the developer solution temperature will give increased contrast.
     – Only Elon in the developing solution will give indistinct contrast.
     – Only Hydroquinone in the developing solution will produce a harsh black and white image. Therefore a combination of Elon and Hydroquinone is used to produce better results and adequate contrast.
     – Film fog, smothers the whole film with a dull gray shadow, giving a very poor contrast.

b. *Subject contrast*: This refers to the characteristics of the subject, that influence radiographic contrast. Subject contrast is determined by:
   - Thickness of the subject.
   - Density of the subject.
   - Composition (atomic number) of the subject.
     – Subject contrast can be controlled by regulating the kilo voltage peak.
     – Increase in kVp (>90 kVp) leads to decrease in subject contrast producing many shades of gray.
     – Decrease in kVp (65-70 kVp) leads to increase in the subject contrast producing areas of distinct black and white.

c. *Operating kilo voltage peak (kVp)*: This is the only exposure factor which has a direct influence on the contrast of a dental radiograph.
   - Increase in kVp, leads to an increase in the energy of the X-rays produced.
     – This leads to increase in the penetrating power of the X-rays,
     – This leads to more variation in the tissue densities recorded.
     – This leads to production of various shades of gray.
     – This produces a decrease in the contrast obtained.
   - Decrease in kVp, produces many areas of black and white with increased contrast.

d. *Exposure time*: An increase in the exposure time will produce increased contrast, but any excessive increase or decrease in the exposure time may decrease the amount of contrast obtained.

As mentioned earlier, the dental radiograph needs to have a compromise between the high and low contrast in order to produce a range of useful densities on a dental radiograph. This is called 'Scale of Contrast';

- Short Scale Contrast is produced by decreasing the kVp which produces black and white areas giving high contrast.
- Long Scale Contrast is produced by increasing the kVp which produces many shades of gray areas giving low contrast.

This scale of contrast can be illustrated by means of a Penetrometer, this is a radiographic testing device, made of aluminum and built up in steps. (Figs 7.2 and 7.3).

For example:

- Enamel has the highest density of all body tissues, but in the mandibular posterior teeth, the X-rays have to penetrate 8 mm of bone, and again on the same radiograph changes in the thin lamina dura around the teeth also has to be recorded.

The lesions in enamel and lamina dura cause changes in the amount of X-rays absorbed by these tissues.

As a result, the intraoral film density is a compromise between a less exposed film that will show the periodontal lesions optimally and a more exposed film which will show carious lesions clearly.

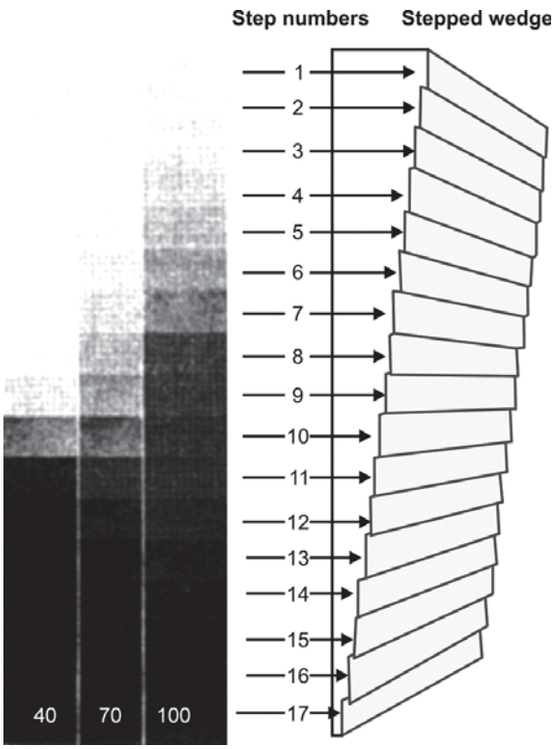


Fig. 7.2: Radiographs taken at 40 kVp are predominantly black and white- that is they have high contrast (a short contrast scale). Those taken at 100 kVp show many shades of gray (a long contrast scale). (From Miles DA, Van Dis ML, Jensen CW, Feroetti A; Radiographic Imaging for Dental Auxiliaries, 2nd ed. Philadephia, WB Saunders, 1993)

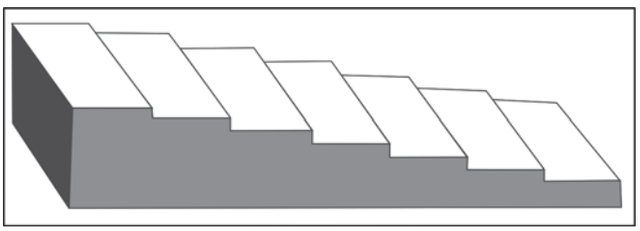


Fig. 7.3: A stepwedge is made of uniform layered thickness

- X-rays are absorbed proportional to the total mass through which they may pass. Thus, a small amount of enamel may absorb the same amount of radiation as that absorbed by a large amount of soft tissue; for example the shadow of the nose and lips which appear on intraoral radiographs, where, the soft tissue mass has sufficient thickness to absorb enough X-rays to create an image.

Relationship between Contrast and Density

When Contrast is altered, the Density is also changed. However, when the Radiographic Density is altered by itself, there is no obvious change in Contrast.

This is because

- Change in kVp produces a change in Contrast and Density.
- Change in mA alone does not change the Contrast.

Thus, if we change the contrast, density also changes, mAs is the prime factor in controlling density, but it is not a controlling factor in Contrast, therefore a change in mAs will produce a change in the radiographic density but with no noticeable change in contrast.

Geometric Characteristics

Alterations in geometric characteristics are mainly due to;

1. X-rays originate from a definite area rather than a point source.
2. X-rays travel in diverging straight lines as they radiate from their source of origin which is an important source of magnification.
3. Dental radiographs are a two dimensional representation of three dimensional structures. This results in unequal magnification of different parts of an object, because of the varying distances of these parts from the film.

iii. Sharpness (also referred to as Detail, Resolution or Definition): Refers to the capability of X-rays to reproduce distinct outlines of an object or to reproduce the smallest details of an object on a dental radiograph.

A certain degree of unsharpness is present in all dental radiographs. The fuzzy, unclear area that surrounds a radiographic image is termed 'Penumbra'.

Penumbra is derived from two latin words;

"pene" meaning almost and "umbra" meaning shadow.

Umbra is defined as that part of the shadow where all light is absorbed, or area of total darkness.

Penumbra is defined as that part of the shadow of an object which is larger than a point and yet represents a single point of the object. It is thus the unsharpness of the image seen at the edge of the image.

The various factors that control sharpness of an image on the X-ray film are:

a. Geometric unsharpness
   - Size of the Focal Spot.
   - Object Film Distance.
   - Target Film Distance.

b. Motion unsharpness
   - Patient.
   - Tube.
   - Film.

c. Film unsharpness
   - Grain Size
   - Single and Double Emulsion.
   - Film Thickness.

d. 'Fog' unsharpness
   - Scattered Radiation.
   - Unsafe, Safety Light in the Darkroom.
   - Chemical Fog.

e. Intensifying screen unsharpness
   - Crystal Size.
   - Back Screen Scatter.
   - Mottle.

a. *Geometric unsharpness*

This type of unsharpness is due to criss-crossing of rays at the edges of the object, resulting in a fuzzy image border.

Size of the focal spot: (Fig. 7.4)

Smaller the focal spot, sharper the image produced.

If a "point source" is used, (normal focal spot size is 0.6 mm^2 to 1 mm^2) no unsharpness is produced.

Object film distance: (Fig. 7.5)

This should be as small as possible, to get a sharper image.

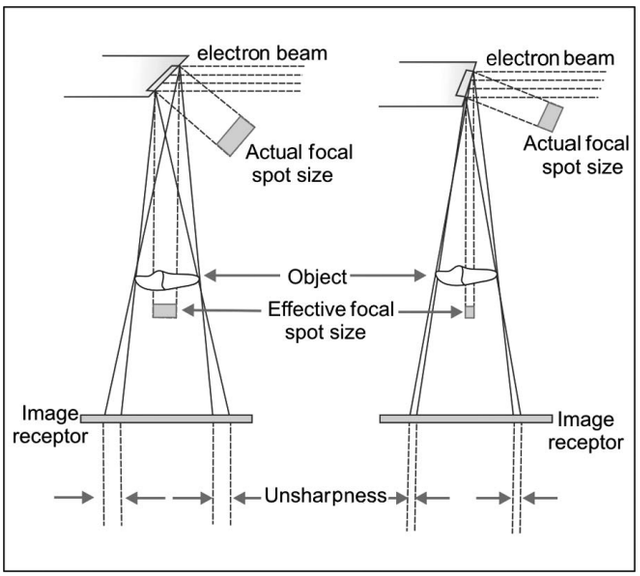


Fig. 7.4: Decreasing the angle of the target perpendicular to the long axis of the electron beam decreases the actual focal spot size and decreases the heat dissipation and thereby tube life. It also decreases the effective focal spot size, thus increasing the sharpness of the image

Target object distance: (Fig. 7.6)

Should be as large as possible, to get a sharper image.

The width of the zone of Geometric Unsharpness or Penumbra can be illustrated by the following equation:

$$Ug = F \times \frac{d}{D}$$

Where, Ug = Penumbra size

F = focal spot size

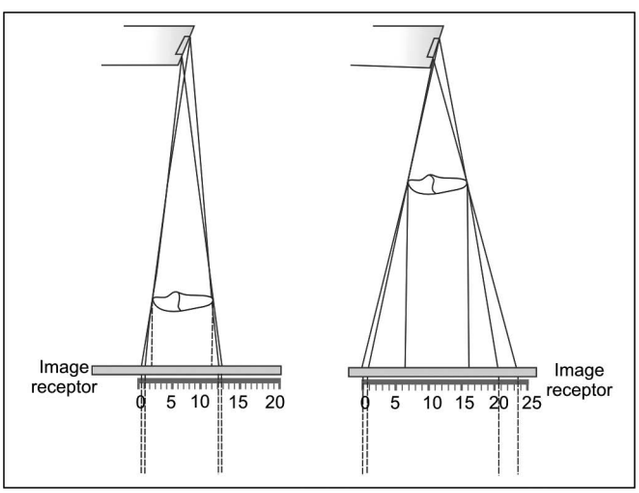


Fig. 7.5: Decreasing the distance between the object and the film increases the sharpness and results in less magnification of the object

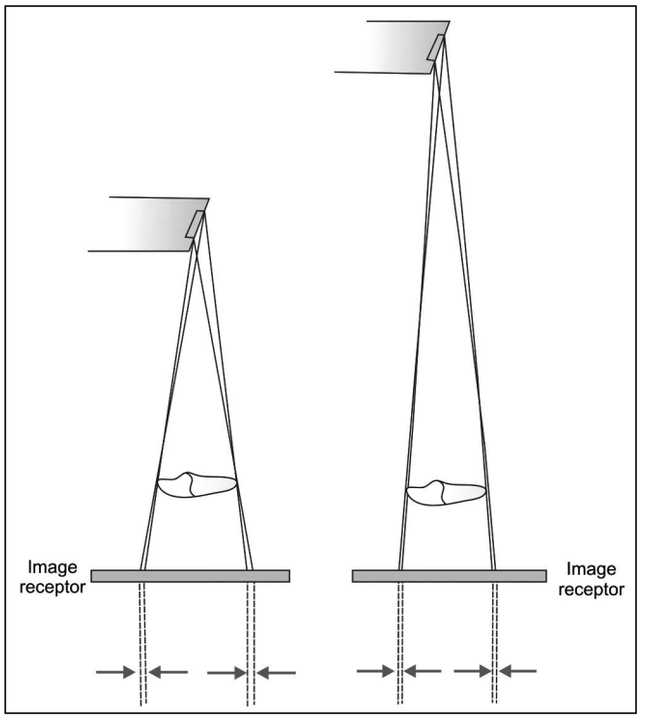


Fig. 7.6: Increasing the distance between the focal spot and the object results in an image with increased sharpness and less magnification of the object

D = Source to object distance in inches.

d = Object to film distance in inches.

In the Dental Radiographs, the portion of the structures closest to the film will have greater sharpness, therefore lingual cusps of teeth have a more sharper image than the buccal cusps, on the dental radiograph.

b. *Motion unsharpness*

Any movement of either the Patient, Tube, or Film, results in unsharpness of the image produced.

A decrease in the exposure time will give less time for movement thus helping to obtain more sharpness on the radiograph.

c. *Film Unsharpness*

Grain Size:

The composition of the film emulsion influences the sharpness of the image produced, which is related to the grain size of the crystal.

Faster the film speed, bigger the grain size of the crystal, produces decreased image sharpness.

This is because larger crystals do not produce image outlines as well demarcated as smaller crystals.

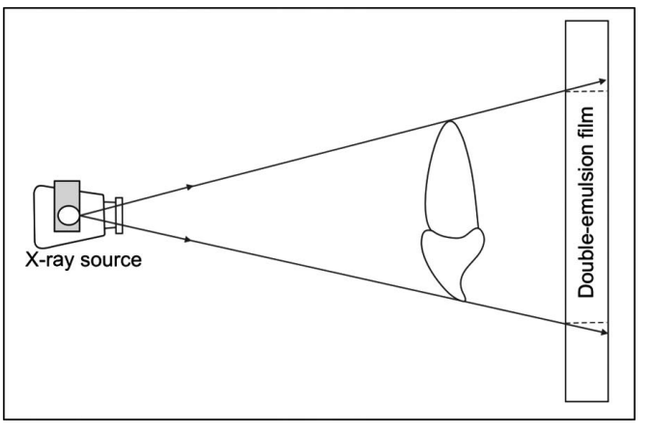


Fig. 7.7: Parallax unsharpness results when double emulsion film is used because of the slightly greater magnification on the side of the film away from the X-ray source

Single and double emulsion and film thickness: (Fig. 7.7)

Use of double coated films leads to increased thickness, which produces unsharpness due to parallax.

d. *Fog Unsharpness*

Scattered radiation:

Scattered, stray, leakage or any other radiation not belonging to the primary beam is undesirable as it produces film fog.

- For intra oral films, filtration, collimation and film packets with lead backed sheets should be used to reduce scattered and secondary radiation.
- For extra oral films grids are used. (Fig. 7.8)

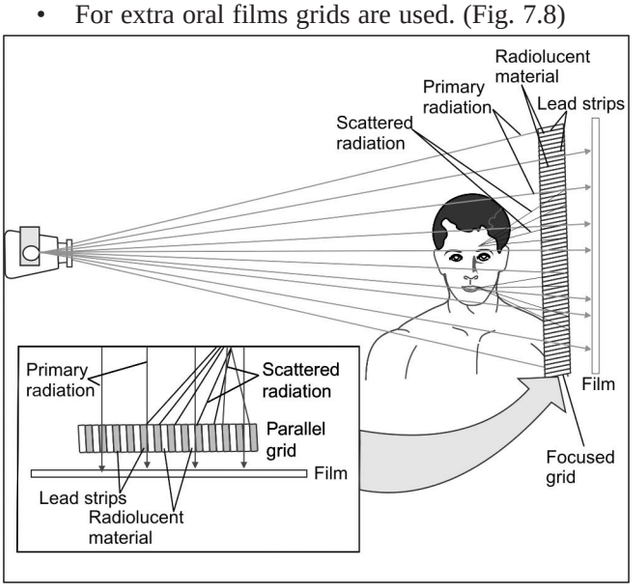


Fig. 7.8: A grid absorbs scattered X-ray photons from the primary beam and prevents them from fogging the film. In a focused grid the absorber plates are angled toward the anode, in a parallel grid the absorber plates are parallel

A grid is a sheet of radiolucent material in which strips of lead are embedded. It is placed between the object and the film and allows only the X-rays which originate from the anode to pass through the object, without any change in direction to reach the film.

The secondary radiations originating in the object and travelling in all directions is absorbed by the lead strips.

But, the disadvantage is that these lead strips produce white lines on the radiograph which decreases the contrast and produces distraction.

Also the exposure time has to be increased when a grid is used. To prevent the grid lines from appearing on the radiograph, a moving grid called Potter Bucky Diaphram is used, but, here too due to the movement of the grid itself there is decreased contrast and density of the image produced, along with unsharpness.

- X-ray film is sensitive to light, pressure and any other type of ionizing radiation. The unexposed silver halide crystals slowly get converted to specks of silver. Therefore, it is important to safeguard the films from excessive temperature, humidity, exposure to chemicals and stray radiations. The films should be used preferably before their expiry date.

Unsafe, safety light in the darkroom:

The safe lights used in the darkroom should be as per the specifications given. Use of unsafe safe light produces fogging which can be verified by performing the "Coin Test", in the dark room.

Chemical fog:

Is produced by prolonged development or development at high temperatures.

- Potassium Bromide or the restrainer prevents chemical fogging of the X-ray film by restraining the action of the developing agents on the unexposed silver halide crystals.
- If the radiograph is not adequately rinsed before putting it in the fixing solution, the alkaline developer will neutralize the acidic fixer and then the fixing and hardening action of the fixer solution is impaired, resulting in stains on the resultant radiograph.
- After fixing the radiograph should be thoroughly washed to remove all residual processing chemicals and silver salts from the film surface, as these may attack the silver image and/or certain products of fixation may decompose and produce a yellowish stain.
- If the temperature difference between the processing solutions and the rinsing water is more than 15°F, an orange peel appearance (reticulations) will appear on the film.
- The film must be adequately dried. If a wet film is touched or splashed with water during the drying process, it will produce spots that cannot be removed.

Potassium alum shrinks and hardens the gelatin so that the radiograph can withstand abuse of normal handling.

e. *Intensifying screen unsharpness*:

Intensifying screens are used in extraoral radiography in order to reduce the exposure to the patient. They may used singly or in pairs, placed in a metal cassette with the film sandwiched between them. They work on the principle of "Fluorescence".

Unsharpness may be caused due to

- Improper film contact with the screens, thus when the X-rays strike the intensifying screen the fluorescent crystals emit light in all directions, producing stray radiations and thus causing unsharpness.
- Screen Mottle.
- Quantum Mottle.

Use of the intensifying screens helps to reduce the exposure time, therefore there are less chances of any movement of patient, tube or film, hence reducing Motion Unsharpness.

iv. *Magnification*:

Refers to a radiographic image that appears larger than the actual size of the object it represents.

This results because of the divergent path of the X-rays from the focal spot. (Fig. 7.9)

Factors which influence magnification of the image are:

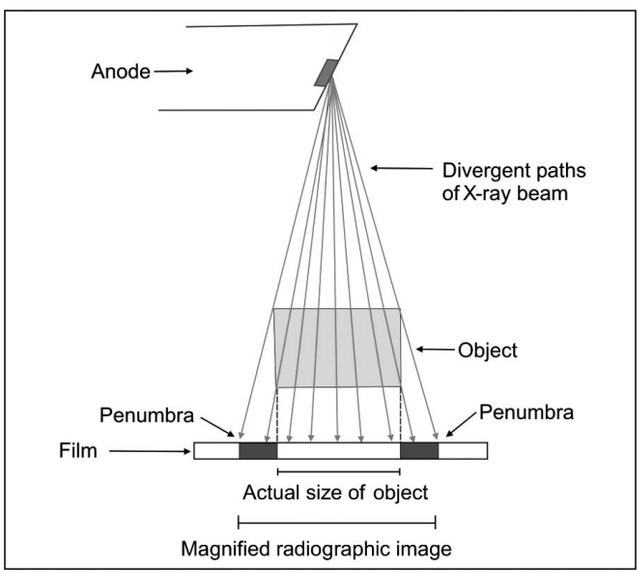


Fig. 7.9: Diagram illustrating magnification as a result of the divergent paths of the X-ray beam

a. *Target film distance*:
This is determined in the intraoral machines by the length of the position indicating device (PID).
- Longer the PID, more parallel X-rays from the middle of the beam strike the object, rather than the diverging rays from the periphery of the beam. Therefore, there is less magnification.
- Shorter the PID, less parallel X-rays from the middle of the beam strike the object, and more of the diverging rays from the periphery of the beam strike the object. Therefore, there is more magnification.

b. *Object film distance*:
- Decrease the film to the object distance, lesser the magnification.
- Increase the film to the object distance, more the magnification.

c. *Use of intensifying screens*:
The use of these screens increases the film to object distance, which produces a certain amount of magnification.
Magnification formulas:
The percentage of magnification of an object at any source film distance and object film distance can be determined by:

$$\frac{\text{SFD}}{\text{SFD - OFD}} - \text{OFD} \times 100\% = \text{Percentage of magnification}$$

Rule for magnification: The actual size of the object is proportional to the size of the projected radiographic image of the object (tooth), as the S-O Distance is to the S-F Distance.

S1 (size of object) = S-O Distance
S2 (size of image) = S-F Distance

v. *Distortion*:
Dimensional distortion of a radiographic image is a variation in the true size and shape of the object being recorded.
A distorted image results from the unequal magnification of different parts of the same object.
This may occur due to: (Fig. 7.10 and 7.11)

a. *Object-film alignment*:
The object and the film should be placed parallel to each other, because if they are not parallel and if an angular relationship results, it will produce variation of the distances between the tooth and the film resulting in distortion.
A distorted image may appear too long or too short.

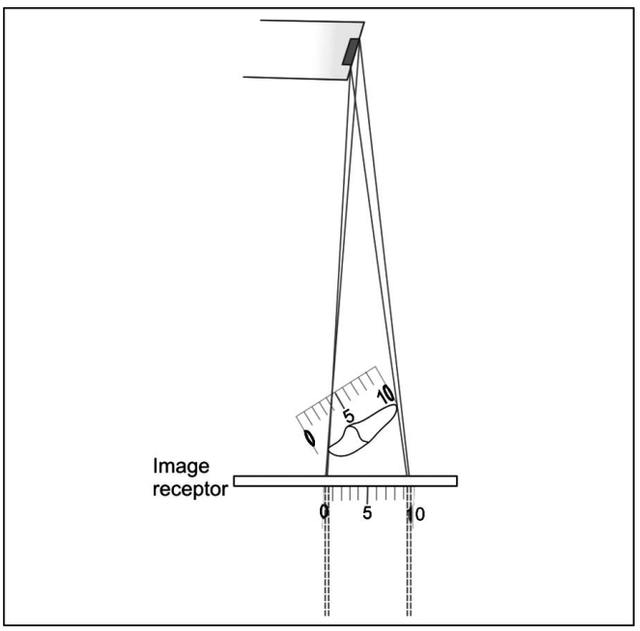


Fig. 7.10: Foreshortening of a radiographic image results when the central ray is perpendicular to the film but the object is not parallel with the film

b. *X-ray beam angulation*:
To minimize dimensional distortion the X-ray beam must be directed perpendicular to the tooth and the film, so as to record the tooth and adjacent structures in their true spatial relationship.

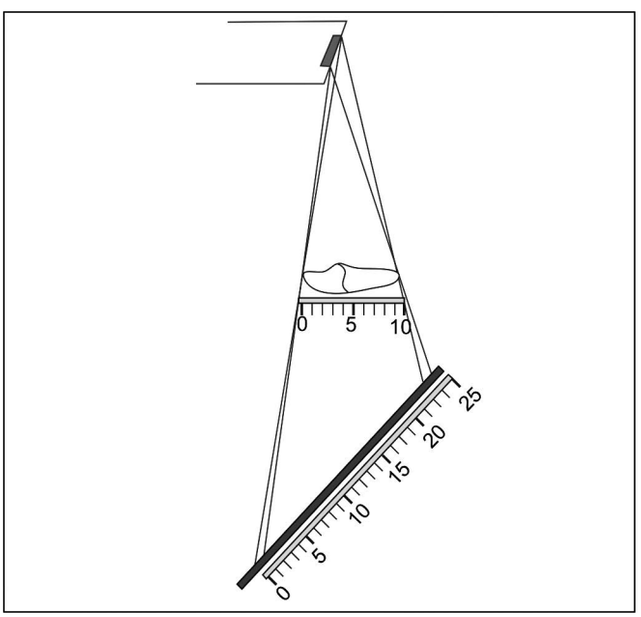


Fig. 7.11: Elongation of a radiographic image results when the central ray is perpendicular to the object but not to the film

Table 7.1: Factors affecting the radiographic quality of a diagnostic film

Image factors	*Clarity*	*Image size*	*Shape Distortion*	*Film density*	*Radiographic Contrast*
kVp				X	X
mAs	X			X	X
Collimation		X		X	X
Filtration				X	X
Focal spot size	X	X			
Object-to-film distance	X	X			
Focal spot-to-film distance	X	X		X	
Motion	X	X			
Alignment			X		
Subject density	X			X	X
Subject shape	X			X	X
Film speed	X			X	X
Developing time				X	X
Technique	X	X	X		
Screen speed	X	X		X	X

If the vertical angulation is increased there will be shortening of the image.

If the vertical angulation is decreased there will be elongation of the image.

If the horizontal angulation is increased mesially or distally there will be overlapping of structures.

The teeth and the alveolar process are units of the facial bone, which are themselves fixed components of the skull. If the head is stabilized,

Table 7.2: Factors affecting the production of an Ideal Radiograph may also be classified as

1. Factors related to the radiation beam
   a. Exposure time
   b. Milli amperage
   c. Kilo voltage peak
   d. Tube film distance
   e. Focal spot size
   f. Collimation
   g. Filtration
   h. Equipment efficiency.
2. Factors related to the absorbing media or object
   a. Object thickness
   b. Object density.
3. Factors related to the technique
   a. Position of patient's head
   b. Placement and position of the film
   c. Angulation of the X-ray beam.
4. Factors related to recording of the roentgen image of the object.
   a. Reduction in secondary radiation
   b. Films and film storage
   c. Intensifying screens
   d. Film processing.

the position of the teeth is automatically standardized.

The plane of occlusion should be parallel to the floor.

The sagittal plane should be perpendicular to the floor.

These two base lines if kept constant, will help reduce errors in the angulation of the beam.

If the height of the palatal arch is more the vertical angulation should be decreased.

c. The film should never be bent in the direction of the long axis of the tooth, and the film holder should be used to prevent movement during exposure.

Anatomical Accuracy this occurs when the anatomical structures are reproduced on the film in exact relationship as they normally appear.

A radiograph with anatomical accuracy will have a minimum of superimposition of images of adjacent tissues. A radiograph is said to have anatomical accuracy when:

1. Labial and lingual cemento enamel junctions of the anterior teeth are superimposed.
2. Buccal and lingual cusps of the posterior teeth are superimposed.
3. Contacts of the teeth are opened in at least one of the projections of a given area.
4. Buccal portion of the alveolar crest is superimposed over the lingual portion of the alveolar crest.
5. There is no superimposition of the zygoma over the roots of the maxillary molars.

For intraoral periapical radiography, more accuracy is achieved by using the paralleling technique.

Radiographic Coverage, it is important that the area of interest is well covered in the radiograph. In case of the intraoral periapical radiograph, an adequate amount of bone surrounding the apices of the teeth should be revealed.

Adequate coverage of the area of interest depends upon several factors:

1. Proper alignment of the film and the radiation beam to the area of interest.
2. Proper selection of the film types.
3. Proper selection of the film projection techniques.

BIBLIOGRAPHY

1. Barr JH, Stephens RG. Image Production with X-rays, In Dental Radiology; Pertinent Basic Concepts and their Application in Clinical Practise. Philadelphia, WB Saunders, 1980; 53-65.
2. Kasle MJ, Lagglais RP. The Quality of Image, Geometric factors, density and Contrast. In Basic Principles of Oral Radiography. Exercise in dental radiology, Vol. 4, Philadelphia, WB Saunders, 1981;56-72.
3. Langland OE, Sippy FH, Langlais RP. Diagnostic Quality of dental radiography. In Text Book of Dental Radiography, 2nd ed. Springfield IL, Charles C. Thomas, 1984;130-51.

8

Faulty Radiographs

Although film processing can produce radiographs of excellent quality, inattention to detail may lead to many problems and images that are diagnostically suboptimal. Poor radiographs contribute to a loss of diagnostic information, loss of professional and patient's time.

Causes of faulty radiographs can be broadly classified into:

A. Projection errors
B. Exposure and processing errors
C. Miscellaneous technique errors
D. Automatic processing errors

A. Projection Errors

1. *Error*: Apical ends of the teeth cut off. (Fig. 8.1)
   i. *Cause*: Film is placed too close to the teeth in the maxillary arch in paralleling technique.
   Correction: Move film away from the teeth.
   ii. *Cause*: Too flat a vertical angulation which causes elongation.
   Correction: Increase the vertical angulation, especially in case of shallow vaults.
   iii. *Cause*: Film not positioned properly in the patient's mouth.
   Correction: No more than 1/8th inch of the film edge should extend beyond the incisal-occlusal surfaces of the teeth.
2. *Error*: Overlapping of teeth. (Fig. 8.2)
   i. *Cause*: Plane of the film not parallel with lingual surface of the teeth.
   Correction: Place film parallel to the lingual surface of teeth.
   ii. *Cause*: Incorrect horizontal angulation of the cone.
   Correction: Direct central ray of the X-ray beam perpendicular to the facial surfaces of the teeth.
3. *Error*: The occlusal plane appears tipped or tilted. (Fig. 8.3)
   i. *Cause*: The edge of the film was not placed parallel to the incisal-occlusal surfaces of the teeth.
   Correction: Make certain that the edge of the film is parallel to the incisal-occlusal surface.
   ii. *Cause*: If the patient is not instructed to hold the film firmly against the tooth, when the finger holding method is used.

Fig. 8.1: Apical end's cut off—Failure to place the film sufficiently apically or an inadequate vertical angulation of the radiographic beam

Fig. 8.2: Overlapping of teeth—this indicates an improper horizontal angulation of the radiographic beam in relation to these teeth

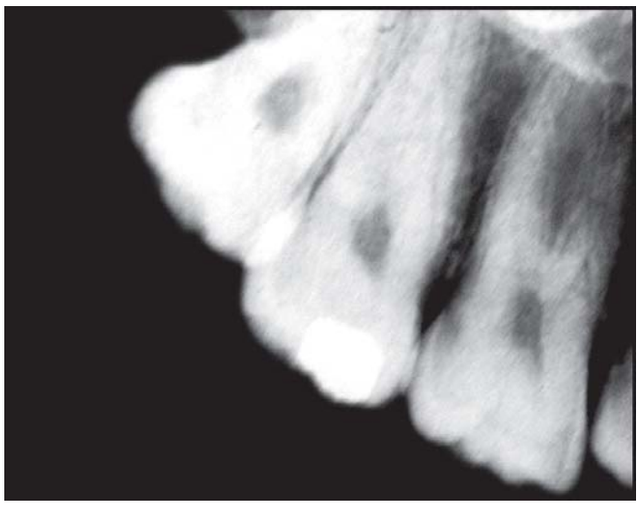


Fig. 8.3: Occlusal plane appears tipped or tilted— The lower edge of the film was not placed parallel to the occlusal surfaces of the teeth. Film may have been moved by the patient just prior to exposure

Correction: Instruct the patient to hold the film firmly.

4. *Error*: All of the specific region not showing. (Fig. 8.4)
   Cause: Faulty film placement.
   Correction: Center the film over the teeth to be radiographed.
5. *Error*: Crowns of teeth not showing. (Fig. 8.5)
   i. *Cause*: Not enough film showing below or above the crowns of teeth.
   Correction: Increase the amount of film showing above or below the crown. Approximately 1/8th of the film should below or above the crown.

Fig. 8.4: Radiograph not depicting all of specific region on the film. The maxillary molar region and the third molar has been "cut-off"

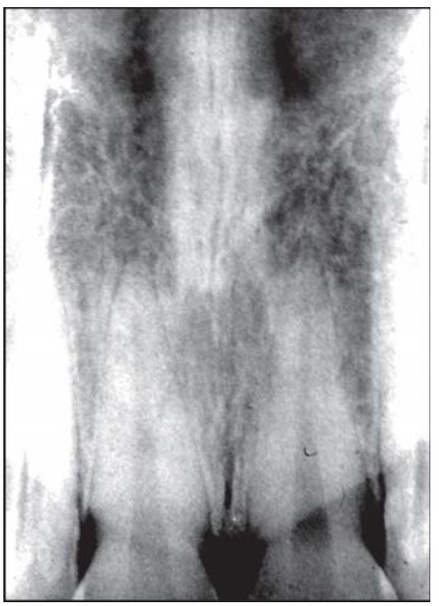


Fig. 8.5: Partial image of the crowns of the maxillary incisors

   ii. *Cause*: Vertical angulation too flat causing elongation.
   Correction: Increase vertical angulation.
6. *Error*: Partial Image (Fig. 8.6)
   a. Cone cut
      i. *Cause*: Cone of radiation not covering area of interest, not using film holder.
      Correction: Make sure that the cone is properly centered over the area of interest and the film, both vertically and horizontally.
      ii. *Cause*: PID not properly aligned with the periapical film holder.

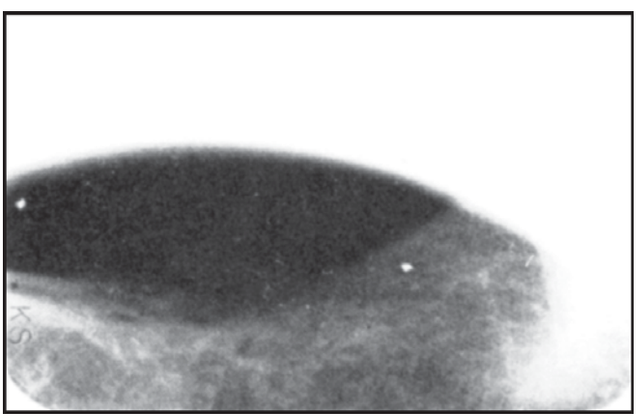


Fig. 8.6: Cone cut

Correction: Position the PID carefully. If a film holder with an aiming ring is used, make sure that the PID and the aiming ring are aligned.

b. iii. *Cause*: Top of the film not immersed in the developing solution.
Correction: Maintain the level of the solution in the processing tanks and make sure that the film is completely immersed during processing.

c. Distal surface of canine not visible on bite wing film.
Cause: The bite wing was positioned too far posteriorly in the mouth; the front edge of the film was not placed at the midline of the canine.
Correction: Anterior edge of the bite wing film should be positioned at the midline of the mandibular canine.

d. Third molar region not visible on the film.
Cause: Bite wing film was placed too far anteriorly in the mouth.
Correction: Make certain that the anterior edge of the bite wing film is positioned at the midline of the mandibular second premolar. Always center the molar bite wing on the mandibular second molar, even when no erupted third molars are present.

e. Only a portion of the film exposed, in panoramic films.
Cause: Film cassette or drum not correctly positioned in the starting position or cassette not correctly placed on the drum.

7. *Error*: Shape distortion.
   a. Foreshortening. (Figs 8.7 and 8.8)
      i. *Cause*: In the bisecting angle technique, the vertical angulation of the cone was too acute.
      Correction: Reduce the vertical angulation.

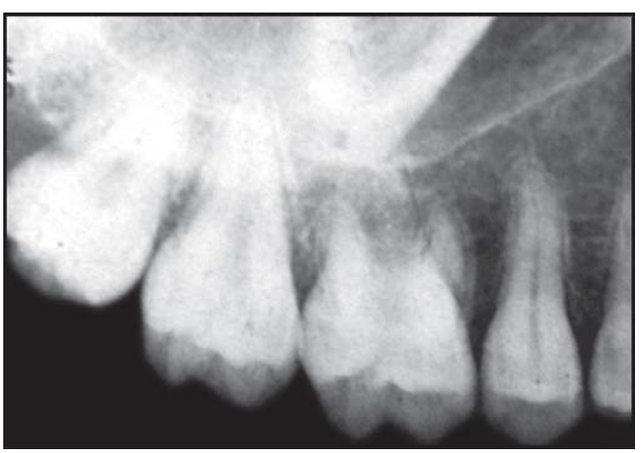


Fig. 8.7: Foreshortening of the roots and superimposition of the zygomatic arch over the maxillary molar apices, this may be due to an excessive positive vertical angulation

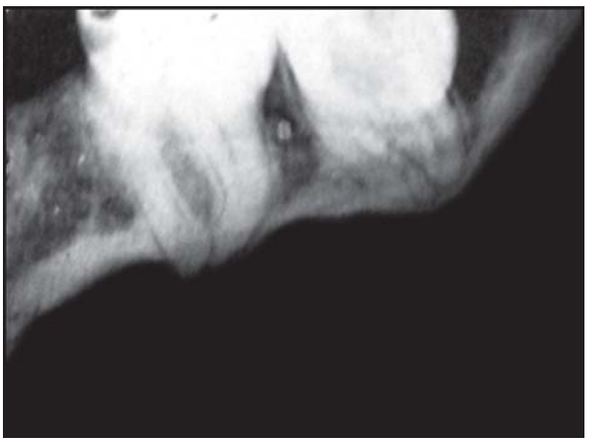


Fig. 8.8: Foreshortening

ii. *Cause:* In the paralleling technique, the film was not placed parallel to the long axis of the teeth.
Correction: Place the film parallel to the long axis of the teeth. This is difficult in case of a shallow vault.

iii. *Cause*: In the paralleling technique, the long cone is not positioned properly.
Correction: Position the long cone so that the central ray strikes the film at right angles. Use position indicating devices.

b. Elongation. (Fig. 8.9)
   i. *Cause*: In the bisecting angle technique, the vertical angulation of the cone was too flat.
   Correction: Increase the vertical angulation.
   ii. *Cause*: In the paralleling technique, the film was not placed parallel to the long axis of the teeth.

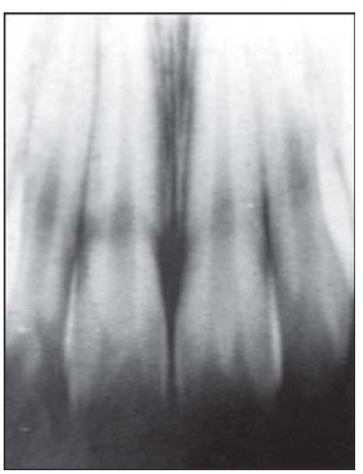


Fig. 8.9: Elongation; this may be due to inadequate positive angulation of the radiographic beam or by failing to have the ala-tragus plane or occlusal plane parallel to the floor in the bisecting angle technique and then not using sufficient vertical angulation of the radiographic beam

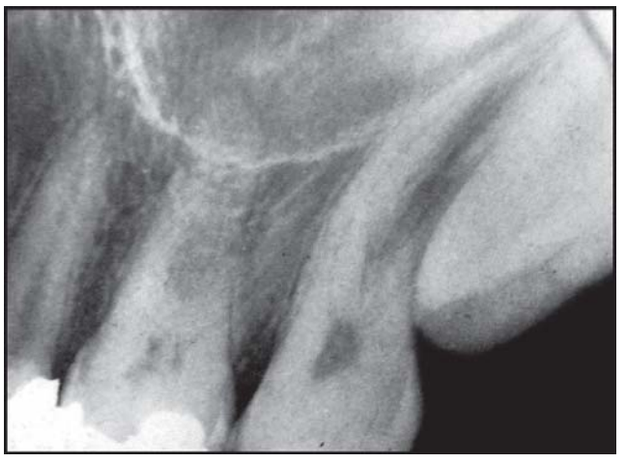


Fig. 8.10: Excessive curving; of the posterior half of the film, which is usually due to excessive digital pressure by the patient while holding the film

Fig. 8.11: Dimensional distortion, which is an inherent error when the bisecting angle radiographic technique is used

Correction: Place the film parallel to the long axis of the teeth. This is difficult in case of a shallow vault.

iii. *Cause*: In the paralleling technique, the long cone is not positioned properly.
Correction: Position the long cone so that the central ray strikes the film at right angles. Use position indicating devices.

c. Image distorted. (Fig. 8.10 and 8.11)
   i. *Cause*: Film is bent as the patient bites on the film holder, bite block or as patient holds the film in the mouth.
   Correction: Use a film backing.
   ii. *Cause*: Negative vertical angulation used in bite wing technique.
   Correction: Always use +10° vertical angulation with bite wing technique.

d. Overlapped contacts. (Fig. 8.12)
   Cause: Central ray was not directed through the inter proximal spaces.
   Correction: Direct the X-ray beam through the inter proximal regions. The use of Rinn instruments minimizes errors in horizontal angulation.

e. Magnification. (Fig. 8.13)
   i. *Cause*: Film to object distance is increased.
   ii. *Cause*: A conical pointed cone is used which produces a divergent beam.

8. *Error*: Herring bone effect or Tyre track appearance: (Figs 8.14A and B)
   Cause: Back side of the film with the lead foil placed facing towards the cone.

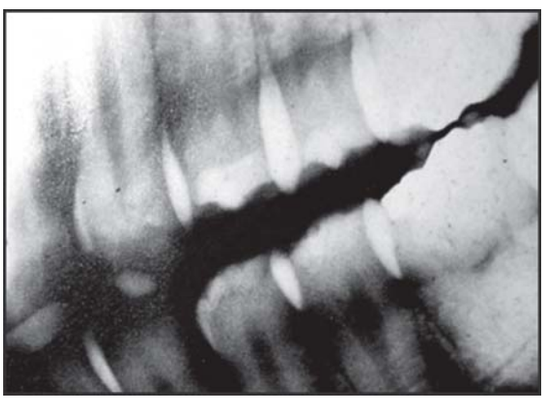
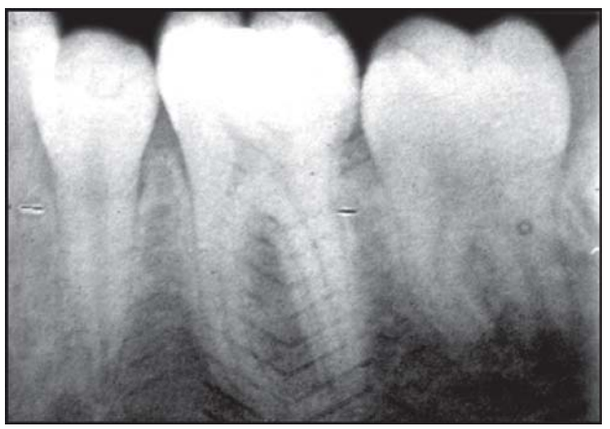


Fig. 8.12: Overlapping of the contacts; this error is usually made by improper horizontal angulation of the beam

Fig. 8.13: Magnification

A


B

Figs 8.14A and B: The film was reversed when placed in the patient's mouth. The tab side of the film packet was facing the beam. The X-rays were partially absorbed by the lead backing; thus the characteristic "tyre tracks" or "herring bone" pattern was produced on the film. The film therefore appears light, underexposed, and foggy.

Correction: Always take care to place the pebbled or the front side of the film towards the cone.

9. *Error*: Black dot in the apical area. (Fig. 8.15)
   Cause: Manufacturers identifying mark on the film placed towards the apical area of the teeth.
   Correction: Always place the raised dot on the film towards the occlusal or the incisal surface of the teeth.
10. *Error*: Artifacts on radiographs
    a. Writing lines on the radiograph. (Fig. 8.16)
       Cause: Writing on the film packet with a ball point pen or a lead pencil.
       Correction: Use a crayon type pencil to mark the film packet.
    b. Black marks on the radiograph. (Fig. 8.17)

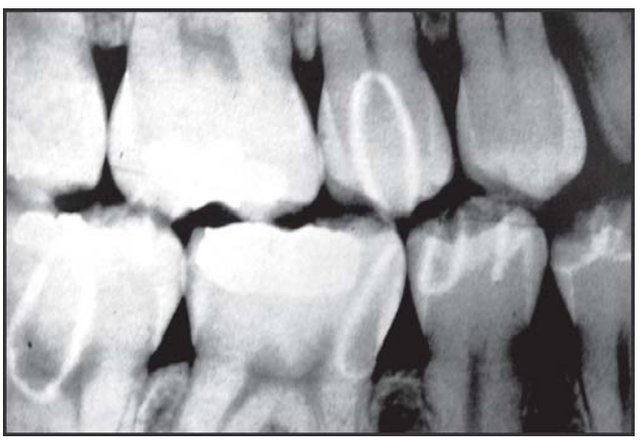


Fig. 8.16: Do not write on the film packet with a pencil or ball point pen as the writing will show through the developed radiograph

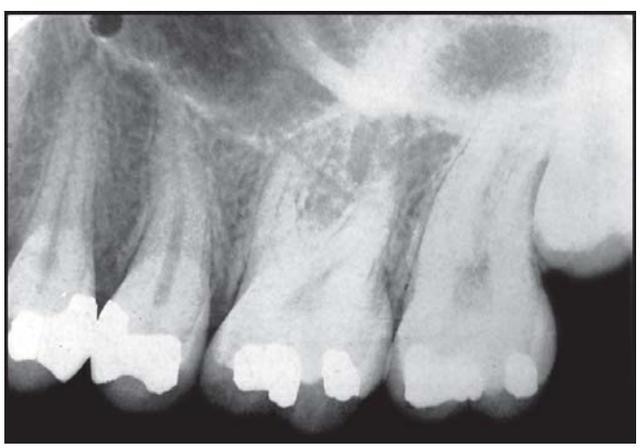


Fig. 8.15: Manufacturers raised dot should be placed toward the incisal or occlusal surface of the teeth during exposure of a periapical film. The dot seen in the given radiograph is superimposed over the apical end of the maxillary first premolar

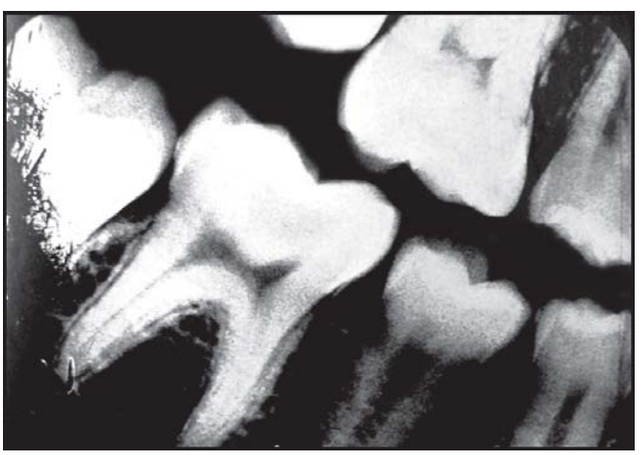


Fig. 8.17: Moisture contamination from failure to blot the film after removal of film from patient's mouth. The black protective paper surrounding the film becomes attached to film emulsion

Cause: Moisture contamination. (failure to blot the film packet)
Correction: Blot film packet immediately after removing from the patient's mouth.

c. Black lines on the radiograph.
Cause: Routine bending of the film to reduce patient discomfort.
Correction: Avoid unnecessary bending of the film.

d. Random artifacts on film (random less density on film).
Cause: Contaminants (paper, felt, dust, etc.) will prevent the X-rays from reaching the film.
Correction: Check screens inside the cassettes for contaminants.

11. *Error*: Double images on the radiograph. (Figs 8.18 and 8.19)
Cause: Film exposed twice to radiation.
Correction: Place exposed film in a separate labeled receptacle.

12. *Error*: Blurred image on the radiograph. (Fig. 8.20)
i. *Cause*: Movement of the film, patient or tube during exposure.
Correction: Use film holders,
- Ask the patient not to move,
- See that there is no play in the tube head.
- Keep the tube ready and do not waste time after positioning the film in the patients mouth and pressing the exposure button.

ii. *Cause*: Double exposure.
Correction: Keep unexposed and exposed film in different receptacle and label the exposed film.

Fig. 8.18: Double exposure

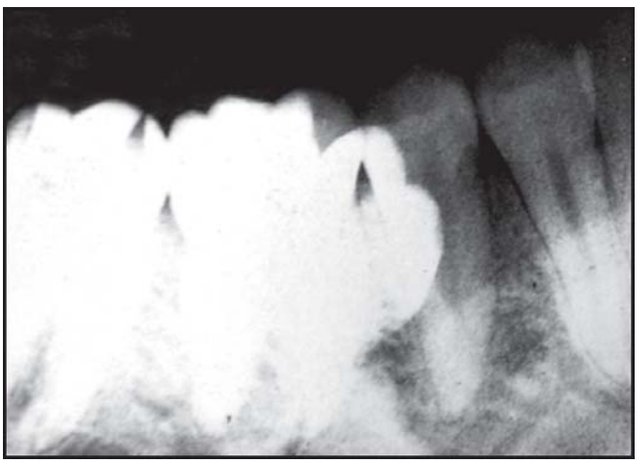


Fig. 8.19: Double exposure, the film was accidently used twice to make intra-oral exposures

13. *Error*: Radiopaque artifacts on the radiograph.
Cause: Leaving dental appliances in the mouth, or presence of foreign bodies in and near the area being radiographed.
Correction: Instruct patient to remove all removable dental appliances and any other foreign bodies like eye glasses, nose ring, ear rings, etc.

14. *Error*: Adumbration (cervical burn out) (Fig. 8.21)
Cause: Horizontal angle of the beam is not directed through the contact area of the teeth.
This 'off' angle may be distal or mesial and causes buccal and lingual segment of the cervical portion of the teeth to appear to be separated, with a relative radiolucency that may be mistaken for cervical caries or root caries.

Fig. 8.20: Blurred image; may be due to patient movement, film movement or movement of the tube head during exposure

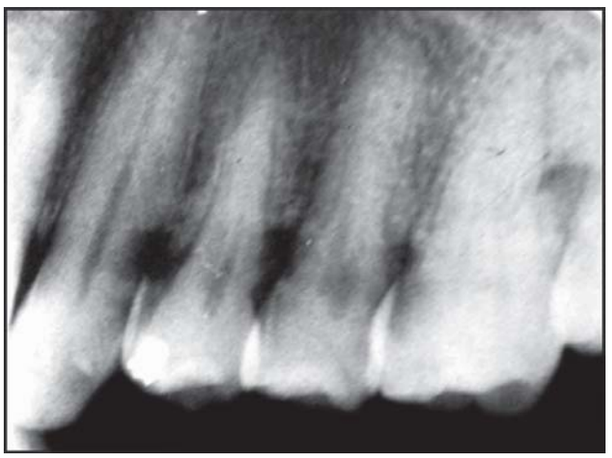


Fig. 8.21: Cervical burn out; Adumbration may be identified by the radiographic appearance or by repeating the radiograph using the proper horizontal angulation. Clinical examination is helpful in ruling out caries

B. Exposure and Processing Errors

1. *Error*: Low density film. (Light Radiograph) (Fig. 8.22)
   i. Under exposure
      a. *Cause*: Too short an exposure.
      Correction: Set exposure time correctly or check calibration of exposure time
      b. *Cause*: Source film distance too great.
      Correction: Check the source film distance.

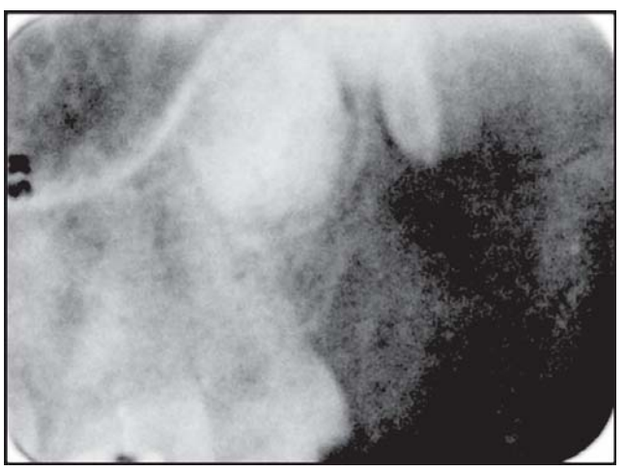


Fig. 8.22: Light Radiograph; may be due to insufficient exposure time, insufficient milliamperage setting (mAs), insufficient mAs factor in relation to the patient's bone density, inadequate development, weak or depleted developer solution, insufficient kilovoltage or expired or aged film

      c. *Cause*: Too low kVp.
      Correction: Increase kVp by approximately 5 kVp.
      d. *Cause*: Too low mA.
      Correction: Increase the mA or the exposure time (mAs is one factor)
      e. *Cause*: Film packet placed with the wrong side facing the tooth. Thus the image of the lead foil is superimposed on the object image.
      Correction: Place the pebbled side of the film facing the tooth and towards the cone.
      f. *Cause*: Drop in the line voltage.
         – Elevators, furnaces, blowers, etc. on the same circuit as the X-ray unit.
         – *Correction*: Use separate circuit for X-ray units.
         – Insufficient size of the power line.
         Correction: Increase size of the power line and or transformer.
      g. *Cause*: In panoramic radiography, if the X-ray beam is not completely aligned with the slot in the cassette holder.
      Correction: Check alignment before exposure.
      h. *Cause*: Incorrect film screen combination used.
      Correction: Always use the right screen film combination.
   ii. Under development.
      a. *Cause*: Improper development.
         1. Time too short.
         Correction: Set dark room timer correct. (check accuracy)
         2. Low developer temperature
         Correction: Raise temperature to 70°F
         3. Inaccurate thermometer
         Correction: Replace thermometer
      b. *Cause*: Exhausted and or contaminated developer
      Correction: Replace developer
      c. *Cause*: Diluted developer
         1. Water added to raise level of developer solution.
         Correction: Add replenisher or replace developer.
         2. Insufficient developer solution added to water.
         Correction: Add more developer solution.
   iii. *Cause*: Excessive fixation.
   Correction: Regulate the time for fixing as per the time table.

2. *Error*: High density film (Fig. 8.23)
   i. Exposure parameters.
      a. *Cause*: Exposure time too long.
      Correction: Set timer correctly and or reduce exposure time.
      b. *Cause*: kVp too high for the exposure time.
      Correction: Reduce kVp.
      c. *Cause*: Source film distance too short for the exposure time.
      Correction: Measure the source film distance and adjust the exposure time accordingly.
      d. *Cause*: Timer inaccurate.
      Correction: Check the timer with spinning top and adjust the time accordingly.
      e. *Cause*: mA too high for exposure.
      Correction: Reduce mA or exposure time.
      f. *Cause*: Incorrect screen-film combination.
      Correction: Make sure that too fast a film and/or screen for the kVp and/or mA setting should not be used.
   ii. Overdevelopment.
      a. *Cause*: Developing time too long.
      Correction: Use time temperature method with a dark room timer.
      b. *Cause*: Developer temperature too high.
      Correction: Lower temperature to 70° F.
      c. *Cause*: Inaccurate thermometer.
      Correction: Replace thermometer.
      d. *Cause*: Over strength developer.
      Correction: Check tank capacity and mixing instructions.
   iii. *Cause*: Inadequate fixation.
      Correction: Fixation time should be standardized as per instruction.
   iv. *Cause*: Accidental exposure to light.
      Correction: All dark room procedures should be done in safelight only.
   v. *Cause*: Improper safe lighting.
      Correction: Safe light should be put as per the recommended requirement of the dark room
3. *Error*: High contrast. (Fig. 8.24)
   i. *Cause*: Insufficient penetration.
      Correction: Increase kilo voltage.
   ii. *Cause*: Over development.
      Correction: See corrections of B. 2. ii.
   iii. *Cause*: Use of film and/or intensifying screens of too high contrast.
      Correction: Use lower contrast film or slower speed screens.
   iv. *Cause*: Too long an exposure.
      Correction: Timer inaccurately set or timer out of calibration.
4. *Error*: Low contrast. (Fig. 8.25)
   i. *Cause*: Excessive penetration. (peak voltage)
      Correction: Decrease kilo voltage.
   ii. *Cause*: Under development.
      Correction: See corrections of B. 1. ii.
   iii. *Cause*: Use of film having insufficient contrast and/or cassettes with too slow intensifying screens.
      Correction: Use of higher contrast films or higher speed screens.

Fig. 8.23: High density or dark radiograph

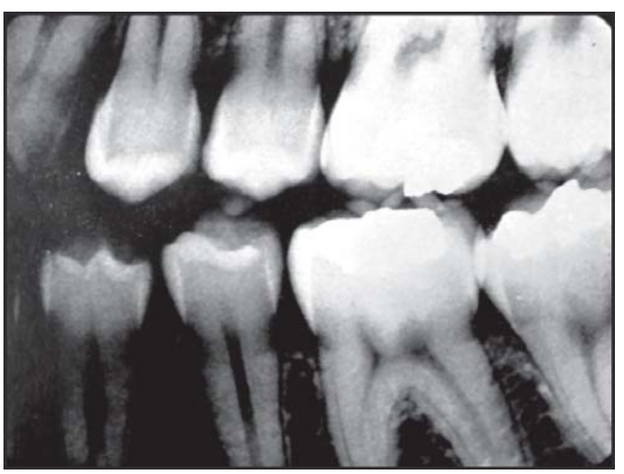


Fig. 8.24: High contrast, usually produced due to exposure techniques utilizing low kVp

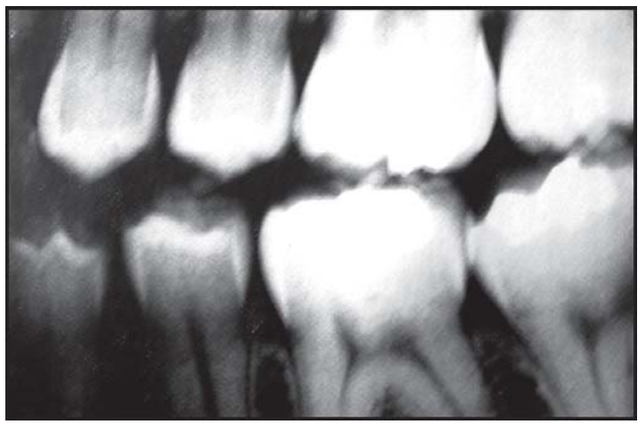


Fig. 8.25: Low contrast, usually produced due to exposure techniques utilizing high kVp. These radiographs have "long scale" contrast which is preferred by dentists

iv. *Cause*: Scattered radiation.
Correction: Check diaphragm size and use suitable cone.
v. *Cause*: Under exposure.
Correction: Check exposure time and set the timer correctly.
vi. *Cause*: Excessive film fog.
Correction: See correction of B 5.

5. *Error*: Fog. (Fig. 8.26)
i. *Cause*: Light.
1. Light leaks in the dark room.

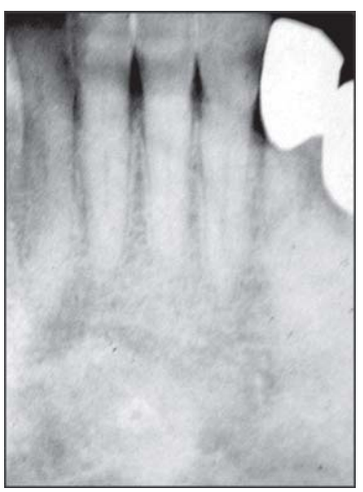


Fig. 8.26: Fogged film; may be due to use of out dated film, storage of film in a warm place, exposure of film to scattered radiation, light leaks in the dark room, excessive proximity of the safe light to the film, improper filtration on the safe light for the type of film used or use of too strong a bulb for the safe light filter used

Correction: Check vents, doors and walls for leaks, cracked safe light filter.
2. Improper safe light.
Correction: Reduce wattage of the bulb, keep adequate (4 feet) distance between safe light and work area.
3. Improper filter in safe light.
Correction: Check type of filter and examine for cracks in the filter. (Wratten 6B type for screen films)
4. Turning over head (white) light on too soon.
Correction: Fix films for 1-2 minutes before turning on the light.
5. Prolonged exposure of films to safe light.
Correction: Reduce exposure time of films to the safe light.
6. Smoking in the darkroom.

ii. *Cause*: Radiation.
1. Insufficient protection.
Correction: Store unexposed films in lead receptacles.

iii. *Cause*: Chemical
1. Developer temperature too high.
Correction: Reduce temperature of developer to manufacturers optimum temperature (70° F)
2. Over strength developer.
Correction: Check tank capacity and mixing directions.
3. Prolonged development.
Corrections: Develop by time temperature method.
4. Contaminated developer.
Correction: Clean developer tank periodically.

iv. *Cause*: Deterioration of the film.
1. Temperature of storage area too high.
Correction: Store film in a cool place (70° F) or use the refrigerator for the storage of films.
2. Humidity of storage area too high.
Correction: Store films in a dry place (50% relative humidity) Use the fridge.
3. Strong fumes (ammonia, paint)
Correction: Keep films away from fumes.
4. Out dated film.
Correction: Limit supply and use older films first.
5. Exposed to radiation.
Correction: Unexposed films should be stored away from source of radiation in a protective compartment.

iv. *Cause*: Improper film screen combination.
Correction: Especially when using high speed films the manufacturer's recommended combination should be followed.

6. *Error*: Streaks on film. (Fig. 8.27)
   i. *Cause*: Failure to agitate during development.
   Correction: Agitate films on immersing them in the developer.
   ii. *Cause*: Undue amount of inspection of film during development. When films are held in front of the safe light during development, the developer solution runs across the films producing uneven reduction of the emulsion.
   Correction: Use time temperature method of development. This reduces the need to inspect the film during development.
   iii. *Cause*: Chemical deposits on hanger clips.
   Correction: Keep hanger clips clean.
   iv. *Cause*: Excessive drying temperature.
   Correction: Reduce air flow over films.
   v. *Cause*: Insufficient fixing.
   Correction: Usually the fixing time should be twice the developing time.
   vi. *Cause*: Dirty or contaminated wash water.
   Correction: Wash films in fresh running water.
   vii. *Cause*: Pre mature exposure of films to white light before the fixing procedure is complete.
   Correction: It usually requires approximately two minutes to clear film in fixing solution.
7. *Error*: Blisters on film.
   i. *Cause*: Unbalanced processing temperatures.
   Correction: Control the temperature of water bath, which in turn controls temperature of processing solution.
   ii. *Cause*: Excessive acidity of fixer.
   Correction: Replace fixing solution.
   iii. *Cause*: Films not agitated when first immersed in fixer.
   Correction: Agitate.
8. *Error*: Reticulation (orange peel appearance) (Figs 8.28 and 8.29)
   i. *Cause*: Sudden extreme temperature changes in processing.
   Correction: Maintain uniform processing temperatures.
   ii. *Cause*: Weakened fixer solution.
   Correction: Replenish or replace fixer solution.
9. *Error*: Frilling.
   Cause: Hot processing solution.
   Correction: Maintain correct processing temperature (70° F)
10. *Error*: Air bells. (Fig. 8.30)
   Cause: Air bubbles trapped on film surfaces preventing uniform reduction of the emulsion.
   Correction: Agitate film upon immersions into developer.
11. *Error*: White spots and lines on films. (Fig. 8.31)
   i. *Cause*: Grit or dust present on the films or upon the screens.
   Correction: Keep darkroom clean to prevent dust and dirt particles from settling on films. Periodically clean screens with commercial screen cleaner.
   ii. *Cause*: Emulsion tears from rough handling of films in processing tanks.

Fig. 8.27: Streaks on film; These may be due to streaks of the developer from a clip that was previously used in concentrated solution. One should wash the film holding clips throughly in clean water before reusing them

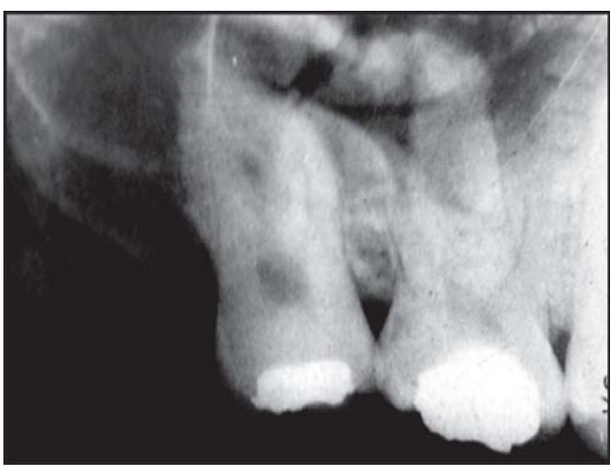


Fig. 8.28: Reticulation; this is crazing of the film emulsion due to extreme differences in processing solution temperatures

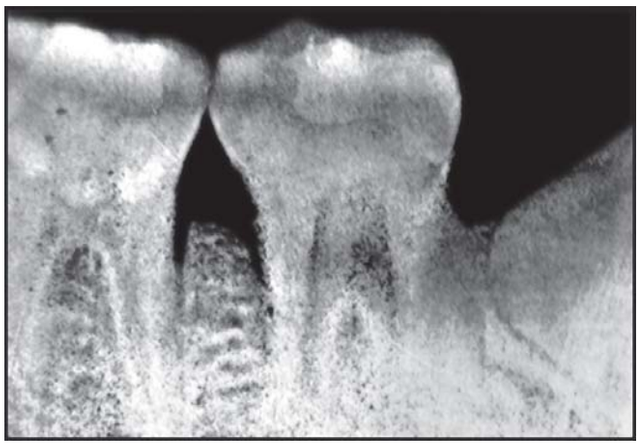


Fig. 8.29: Reticulation

Correction: Do not rub films up against the sides of tanks or other film hangers.

iii. *Cause*: Film contamination with fixer before processing.
Correction: Keep the dark room clean and dry.

iv. *Cause*: Excessive bending of film.

v. *Cause*: Films handled roughly while being mounted on hangers.

vi. *Cause*: Cracks in the intensifying screens.

vii. *Cause*: Finger contamination, where the contaminant is the fixer.

12. *Error*: Black spots on films. (Figs 8.32 and 8.33)

i. *Cause*: Grit or dust in contact with the undeveloped film.
Correction: Prevent fine particles of developer coming in contact with film (dry chemicals).

Fig. 8.30: Air bubbles trapped on the film surface, which prevents film development, resulting in white spots on the film called air bells

Fig. 8.31: White line caused by scratching of the emulsion in processing tanks

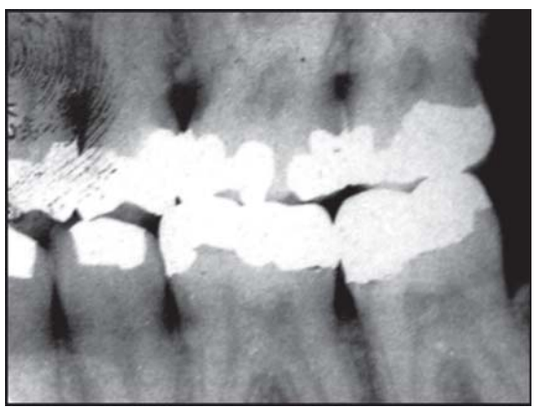


Fig. 8.32: Black marks; may be due to handling of the film with fluoride contaminated fingers or contamination from developer solution

Fig. 8.33: Finger nail artifact

ii. *Cause*: Film splashed with developer before being placed in developer tank. (Fig. 8.34)
Correction: Careful handling of solutions and clean work area.
iii. *Cause*: Films touching during exposure.
Correction: Films should not touch in the processing tank.
iv. *Cause*: Black wrapping paper sticking to film surface.
Correction: Remove the black paper carefully, with dry hands.
v. *Cause*: Excessive bending of the film. Film is bent excessively owing to the curvature of the hard palate or heavy finger pressure on the film. As a result stretched and distorted images are seen on the radiograph.
Correction: To avoid film bending always check the film placement before exposure. If the patient's finger pressure is excessive, instruct the patient to stabilize the film gently. If the film is bent because of the curvature of the hard palate, cotton rolls can be used with the paralleling technique, or the bisecting angle technique used. Film holding devices are helpful in preventing film bending.
vi. *Cause*: Finger contamination where the contaminant is the developer.
Correction: Wash hands properly.
vii. *Cause*: Finger contaminants with fluoride compounds, such as stannous fluoride.
Correction: Wash hands with soap and water, or wipe with a mild acid such as vinegar or lemon juice, to remove the fluoride contaminants.
viii. *Cause*: Finger nail artifact

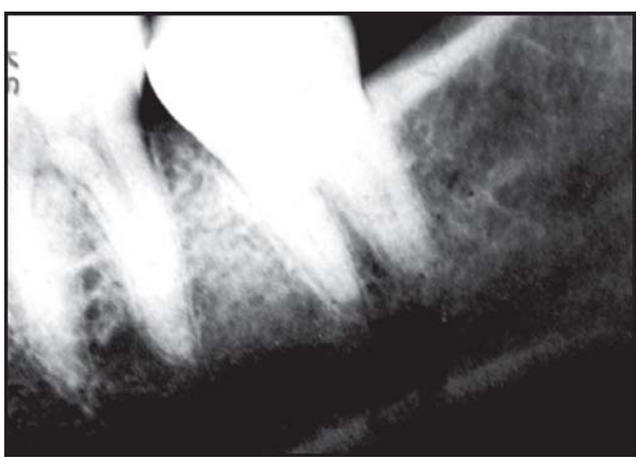


Fig. 8.34: This black spot looks like a fistula but it is due to the developer splashed on the film prior to developing

13. *Error*: Artifacts from processing.
a. Black crescents.
Cause: Rough handling of films.
Correction: Handle films by edges only.
b. Black Smudge marks.
Cause: Finger prints of finger abrasions.
Correction: Have dry fingers when handling film (processing and mounting).
c. Black lines.
i. *Cause*: Static electricity. (Fig. 8.35) (naked tree, lightening marks), these are caused by electrical discharges that produce no visible light, but occur on the surface of the emulsion.
- Rapid movement in removing film from the box.
- Film is removed rapidly from the interleaving paper.
- Film is touched by the fingers of the person processing the film.
- Lack of moisture in the air (especially in winter).
- Static electricity. (Smudge markings), these may result from visible light produced by sparks caused by a relatively low potential electrical discharge in the air next to the film surface. The discharge follows a path induced by dust, lint, or a roughened intensifying screen.

Correction:
- Install an electric humidifier or cool vapor vaporizers in the dark room. The relative

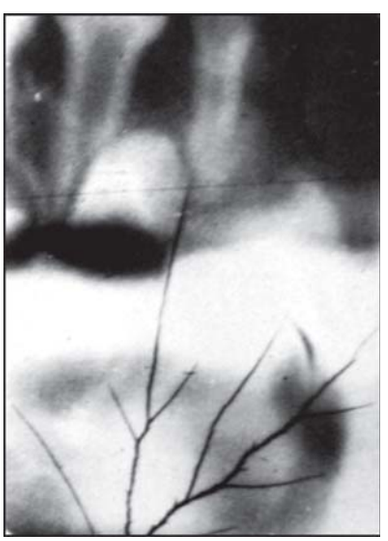


Fig. 8.35: Static electricity

humidity in the dark room should be between, 50% to 75%.
- Do not remove the X-ray film too rapidly from the packet.
- Handle the film gently and let the paper fall away from the film, and place the film in the cassette gently.
- Following exposure remove the film gently from the cassette.
- Coat the intensifying screens in the cassette with an antistatic solution.

ii. *Cause*: Film creasing, and the film emulsion cracks. As a result a thin radiolucent line is seen on the radiograph.
Correction: Do not bend or crease the film excessively. Instead gently soften the corners of the film before placing it in the patient's mouth.

14. *Error*: Stains on film.
   a. Yellow or Brown. (Fig. 8.36)
      i. *Cause*: Exhausted developer.
      Correction: Replace developer solution.
      ii. *Cause*: Oxidized developer.
      Correction: Keep developer covered.
      iii. *Cause*: Prolonged development.
      Correction: Use correct development time.
      iv. *Cause*: Insufficient rinsing.
      Correction: Rinse films for 15 to 20 seconds in fresh running water.
      v. *Cause*: Exhausted fixer solution.
      Correction: Replace fixer solution frequently.
      vi. *Cause*: Contaminated solutions.
      Correction: See that no mixing of solutions occurs when the radiograph is transferred from one tank to another.

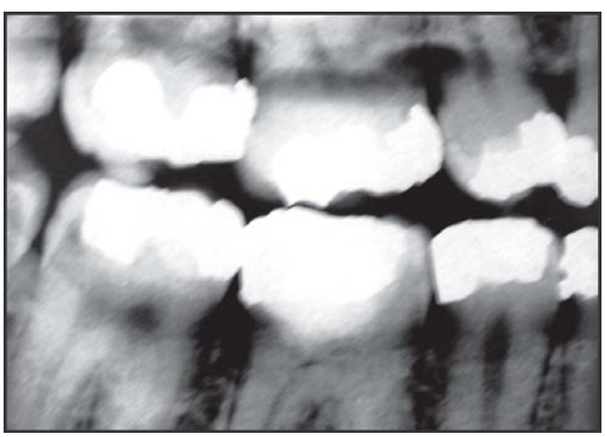


Fig. 8.36: Brown stain on film caused from insufficient rinsing of the film between the developing and fixing process

   b. Dichroic (showing two colors)
      i. *Cause*: Old or exhausted developer.
      Correction: Replace developer solution.
      ii. *Cause*: Nearly exhausted fixer.
      Correction: Replace fixer solution.
      iii. *Cause*: Developer containing small amounts of scum or fixer.
      Correction: Remove scum and/or replace fixer solution.
      iv. *Cause*: Film partially fixed in weak fixer, exposed to light and washed.
      Correction: Replace fixer solution and follow the recommended processing cycle.
      v. *Cause*: Prolonged intermediate rinse in contaminated rinse water.
      Correction: Use fresh, running water and recommended cycle.

15. *Error*: Deposits on film.
      i. *Cause*: Contaminated solutions (oil, impurities).
      Correction: Make new solutions.
      ii. *Cause*: Chemical deposits on hangers.
      Correction: Clean clips and hanger tops.
      iii. *Cause*: Grit from dirty water.
      Correction: Use fresh running water.
      iv. *Cause*: Metallic deposits (oxidized products from developer).
      Correction: Replace developer solution.
      v. *Cause*: Fixer contains excessive amounts of silver.
      Correction: Replace fixer solution.
      vi. *Cause*: White deposits (use of fixer which has milky appearance. This is caused by excessive amounts of aluminum sulphite.)
      Correction: Follow manufacturer's instruction for mixing fixer solution.
      vii. *Cause*: Excessive amount of developer carried into fixer on film emulsion.
      Correction: Rinse properly and allow developer solution to drip into water for a few seconds before placing film in fixer.

16. *Error*: Clear film. (Fig. 8.37)
   a. Film not exposed.
      i. *Cause*: Failure to switch on the X-ray machine, electrical failure, malfunction of machine.
      Correction: Ensure that the X-ray machine is working properly.
      ii. *Cause*: Exposed film first put in the fixing solution.
      Correction: The position of the tanks containing the solutions should be fixed, as per the requirement of a dark room.

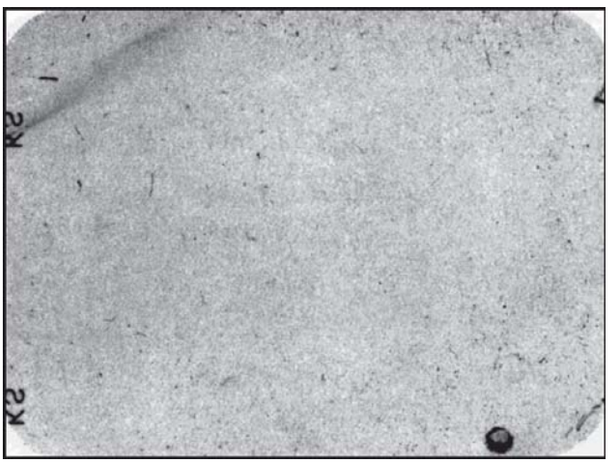


Fig. 8.37: Clear or blank film; this occurs when the time exposure button is not depressed long enough to make adequate exposure or if the film is accidently placed in the fixer solution first, then the image is completely wipped off the film.

17. *Error*: Black film. (Fig. 8.38)
    Cause: Film exposed to light.
    Correction: Handling of the exposed and unexposed film should be done carefully.
18. *Error*: Brittleness of finished radiographs.
    i. *Cause*: Excessive drying temperature.
    Correction: Reduce dryer temperature.
    ii. *Cause*: Excessive drying time; incoming air too humid and cold air velocity too low.
    Correction: Use the dryer and reduce the drying time and adjust the incoming air. Use a wetting agent prior to placing films in dryer
    iii. *Cause*: Excessive fixer acidity.
    Correction: Replace fixer solution.
19. *Error*: Faded image on finished radiograph (radiopaque appears radiolucent).
    i. *Cause*: Exhausted fixer.
    Correction: Replace fixer solution.
    ii. *Cause*: Inadequate fixing.
    Correction: Fix films for a time duration three times the clearing time.
    iii. *Cause*: Insufficient final wash.
    Correction: Wash films in fresh running water for a minimum of 15-20 minutes.
    iv. *Cause*: Kinking.
    v. *Cause*: Blank film.
    vi. *Cause*: Partially developed film.
20. *Error*: Dark flow marks.
    Cause: Vigorous agitation results in solution currents that may form dark flow marks. This is a common occurrence with a weak developer or high temperature development or insufficient agitation when the film is developed vertically, it may produce dark and light drainage streaks below low and high density areas respectively. Such streaks occur because alkali bromide, a by product of development, interferes with the developing process. An area of high density forms a local concentration of alkali bromide that drains downwards and restricts the development in the low density area. Conversely an area of low density contains less alkali bromide on development, hence relatively fresh developer drains down and increases development in the high density area.
21. *Error*: Emulsion peel.
    i. *Cause*: Abrasion of image during processing.
    ii. *Cause*: Excessive time in wash water.
22. *Error*: Grainy appearance. (Fig. 8.39)
    Cause: Developer solution too warm.

Fig. 8.38: Black film; film exposed to white light or day light, or improperly filtered safe light or a film exposed for too long

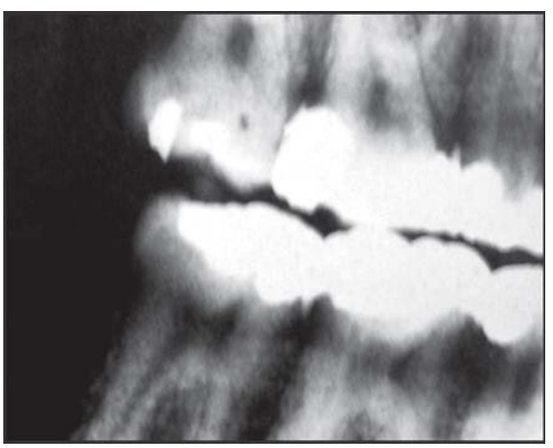


Fig. 8.39: Grainy appearance; may be due to developer solution being too warm, the optimal temperature is 68 degrees F

23. Error: Vertical white line on panoramic radiograph. (Fig. 8.40)
    Cause: The push button on the exposure switch is accidently released and then pressed down for the remainder of the excursion, a blank space on the panoramic radiograph will result, as the radiation to the film is cut off.
    Correction: Keep the exposure button properly pressed till the entire exposure cycle is through.

C. Miscellaneous Technique Errors

1. *Error*: Phalangioma. (patient's finger on the film) (Fig. 8.41)
   Cause: The patient's finger was incorrectly positioned in front of the film instead of behind the film. As a result the patient's finger appears on the radiograph. The term phalangioma was coined by Dr David F. Mitchell of the Indiana University of dentistry. It refers to the distal phalanx of the finger seen in radiographs. [A phalanx (phalanges) is any bone of a finger or toe]. This error occurs when the finger holding method is used with the bisecting angle technique.
   Correction: To avoid phalangioma, make certain that the patient's finger used to stabilize the film is placed behind the film and not in front of it.

D. Automatic Processing Errors

I. Film density problems.
   1. *Error*: Decrease in film density (over all light films).
      i. *Cause*: Developer temperature low.

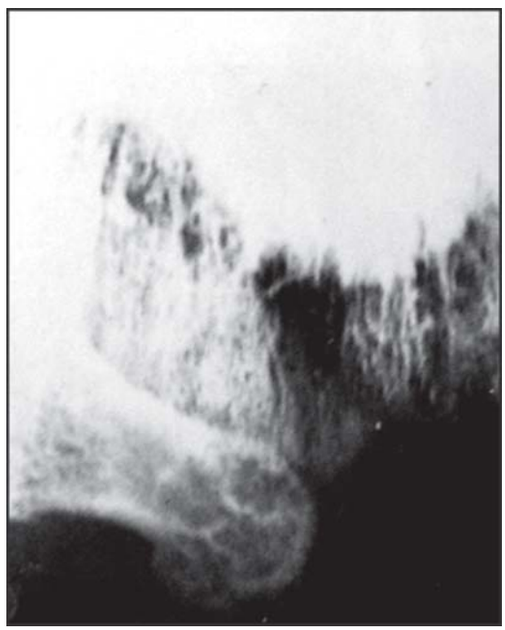


Fig. 8.41: Phalangioma, patient's finger

Correction: Increase heat in the developer. *Note*: Check temperature of the developer solution with a thermometer of known accuracy.

ii. *Cause*: Developer reaching exhaustion.
Correction: Drain and throughly clean tank; install new developer.

iii. *Cause*: Developer contamination. The most likely reason for contaminated developer is fixer solution splashed or dripped into the developer.

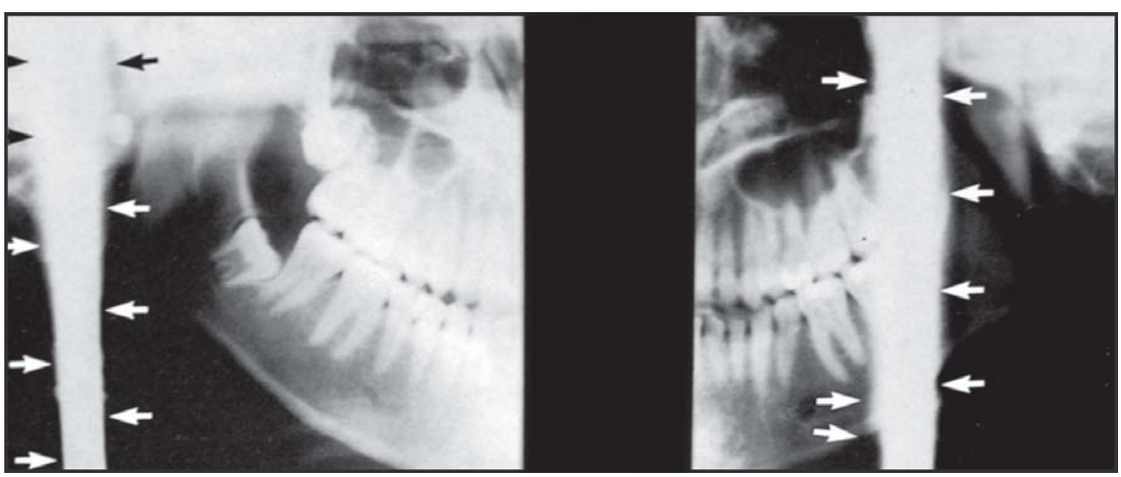


Fig. 8.40: White vertical bands appearing on processed panorex radiograph as a result of accidently releasing the exposure switch and then pressing down for the remainder of excursion

Correction: Drain and throughly clean tank.; install new developer.

iv. *Cause*: No agitation in developer tank.
Correction: Be sure that the agitator paddle drive belt is in the proper position in the pulley.

v. *Cause*: Processing too fast.

2. *Error*: Increase in film density (overall dark films). (Fig. 8.42)
   i. *Cause*: Developer temperature too high.
   Correction: Check that the water is not turned off. Check temperature of the incoming water supply and adjust between 75° to 78° F. Decrease the heat in the developing solution, *Note*: Check temperature of the developer solution with a thermometer of known accuracy.
   ii. *Cause*: Light leaks in processor cover.
   iii. *Cause*: Too much replenisher.
3. *Error*: Streaking (uneven density)
   i. *Cause*: Developer and fixer replenishment low.
   ii. *Cause*: Rollers and crossovers encrusted with chemical deposits.
   iii. *Cause*: Dirty wash water.
   iv. *Cause*: Improper chemicals and/or films used.
   v. *Cause*: Films not hardened properly by chemicals.
4. *Error*: Fogged films.
   i. *Cause*: Developer solution contaminated with fixer.
   Correction: Drain and throughly clean tank and rack. Install new developer solution.
   ii. *Cause*: Processor light leaks.

Fig. 8.42: Over all dark film, may be due to, the film being overexposed, overdeveloped or the developing solution was improperly mixed, producing an over concentrated solution, or a light leak in the processing dark room

Correction: Be sure processor cover is secure and firmly in place.

iii. *Cause*: Light leaks in other areas.
Correction: Check light tightness of the dark room.

iv. *Cause*: Improper safe light.
Correction: Use 7½ watt frosted bulb in safe light with a proper filter mounted no closer than 4 feet from the working area.

v. *Cause*: Heat fog.
Correction: Make sure that the film storage area is not excessively hot.

vi. *Cause*: Excessively high developer temperature.
Correction: Readjust developer thermostat and water to proper temperature.

II. Film drying problems.

1. *Error*: Films are not dry.
   i. *Cause*: Depleted fixer.
   Correction: Install new fixer solution.
   ii. *Cause*: Insufficient water flow (film not properly washed).
   Correction: Check incoming water line and valves.
   Note: Incoming water flow must be a minimum of ½ gallon-per-minute – or a maximum of 1 gallon-per-minute.
   iii. *Cause*: Dryer temperature setting too low.
   Correction: Increase dryer temperature.
   iv. *Cause*: Dryer thermostatic control or heater inoperative.
   v. *Cause*: Dryer air circulation inadequate (high humidity in dryer section)
   vi. *Cause*: Chemical imbalance (either developer or fixer).
   Correction: Replace with new solution.
   vii. *Cause*: Improper type of film for time cycle of processor.
   Correction: Check with dealer for information regarding proper type of film. (it is not recommended for film with acetate film base or any other film not designed for automatic processing).
   viii. *Cause*: Processing too fast.

III. Abnormal film surface marks.

1. *Error*: Peeling of the emulsion.
   i. *Cause*: Developer temperature too high.
   Correction: Reduce developer temperature to proper level.
   ii. *Cause*: Improper fixer strength or depleted fixer.
   Correction: Replace fixer solution.
   iii. *Cause*: Heavy developer deposits on developer rack rollers above solution level.

Correction: Be sure to follow the recommended house keeping and cleaning procedures.

iv. *Cause*: Improper film.
Correction: Check with the dealer for information regarding the proper type of film.

v. *Cause*: Rough handling of films prior to processing.

2. *Error*: Pressure marks.
   i. *Cause*: Foreign material or rough spot on roller.
   Correction: Clean rollers and/or remove rough area on roller.
   ii. *Cause*: Rough handling or excessive hand pressure on film before processing.
   Correction: Film emulsions are extremely sensitive, particularly after exposure and before the processing. Good habits in gentle handling of film must be practiced.
3. *Error*: Cloudy or smudge appearance on film surface (greenish or yellowish).
   i. *Cause*: Depleted fixer.
   Correction: Replace fixer solution.
   ii. *Cause*: Improper type of film for time cycle of processor.
   Correction: Check with dealer.
4. *Error*: White cloudy appearance over film surface.
   Cause: No water in water tank.
   Correction: Check incoming controls and lines. Be sure that the drain plug in wash tank is inserted in drain outlet.
5. *Error*: Scratches on film surface.
   i. *Cause*: Foreign material on roller(s).
   Correction: Clean rollers.
   ii. *Cause*: Improper handling of film before processing.
   Correction: Proper gentle handling of film must be practiced.
   iii. *Cause*: Damaged or defective film.
   Correction: Hand develop film(s) of the same batch or box. This may pick up defects that could be characteristic of the particular box or batch of film.
   iv. *Cause*: Stalled or sticking roller.
   Correction: Inspect racks, gears and gear mesh. Correct as required.
6. *Error*: Drying pattern on film surface.
   i. *Cause*: Dryer too hot.
   Correction: Reduce dryer temperature.
   ii. *Cause*: Characteristic of film.
   Correction: Process film of the same box through other processor and chemicals to determine consistency of pattern.
7. *Error*: Dark spots or lines. (Fig. 8.43)
   i. *Cause*: Excessive roller pressure.
   Correction: Check with manufacturer or get the processor serviced.
   ii. *Cause*: Dirty rollers in the processor.
   Correction: Clean rollers carefully.
   iii. *Cause*: Contamination of the film by dirty work bench or water droplets.
8. *Error*: Broad horizontal white line.
   Cause: Irregularities on the surface of the rollers.
9. *Error*: Film discoloration.
   i. *Cause*: Fixer in developer (brown stains)
   ii. *Cause*: Processing too fast.
   iii. *Cause*: Exhausted fixer.
10. *Error*: Shiny films.
    i. *Cause*: Excessive hardening.
    ii. *Cause*: Wash water not turned on.
11. *Error*: Films chalky or dirty.
    i. *Cause*: No wash water or dirty wash water.
    ii. *Cause*: Precipitate in fixer.

IV. *Error*: Jam or failure of films to transport.
   i. *Cause*: Chemicals contaminated or diluted.
   ii. *Cause*: Chemical temperature too high.
   iii. *Cause*: Films excessively soft and not adequately hardened, when enough gelatin lubricates the rollers, the films will jam up with one another.

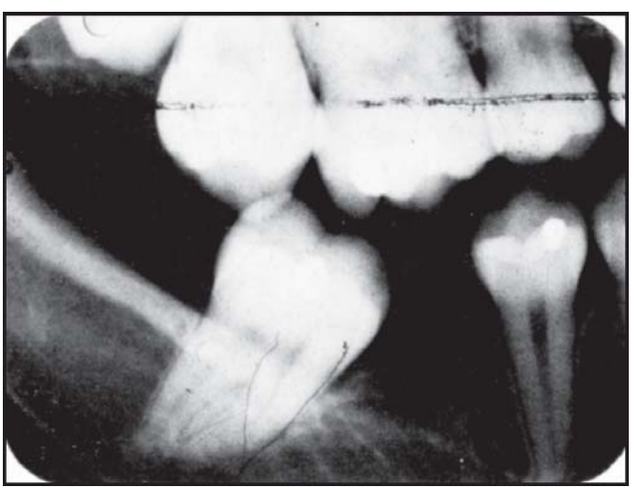


Fig. 8.43: Dark spots or lines; due to the rubber rollers of the automatic machine, the rubber may actually come off the roller and adhere to the processed radiograph. Here static electricity can be seen superimposed over the mesial root of the mandibular molar

iv. *Cause*: Dirty rollers.
v. *Cause*: Incorrect dryer temperature.
vi. *Cause*: Racks not seated properly.
vii. *Cause*: Dirty wash water.
viii. *Cause*: Hesitation in drive assembly, causing film to pause in transit.
ix. *Cause*: Film not tracking through processor in straight course (improper feeding of films).

BIBLIOGRAPHY

1. A Look at X-ray Film Processing, Milwaukee, X-ray Department, General Electric Co.
2. Dark Room Technique for Better Radiographs. Wilmington, Delware, Photo Products Department, E.I. du Pont de Nemours and Co.
3. Mason and Hing LR. Radiographic Quality and Artifacts. In Fundamentals of Dental Radiography 3rd ed, Philadelphia, Lea and Fegiger, 1990; 40-45.
4. Profexray's Automatic Dental Processor's Manual.

9 X-ray Films and Accessories

The *X-ray film* is the image receptor system used in dental radiology. The image reception is modified by the composition of the film and also the use of intensifying screens and grids.

The X-ray films, help us to record the information regarding the object (tissue) through which the X-rays pass and hence they greatly help in diagnosis and treatment of the patient problem.

The X-ray films are *classified* according to:

A. Their use;
   a. Intraoral films
      i. Periapical films
         - No 0 for children.
         - No 1 for anterior adult projections.
         - No 2 for standard adult projections.
      ii. Occlusal films.
      iii. Bite wing films.
   b. Extraoral films.

B. The coating of emulsion
   a. *Single coated*: These produce better and sharper images but the exposure to the patient is more, therefore mostly used in Industrial Radiography.
   b. *Double coated*: These films have emulsion on both sides. Most dental films are double coated. These allow for less exposure to the patient.

C. The speed of the film
   a. *Slow films*: These have a very small grain of silver bromide and emulsion is on one side only. Therefore it gives better definition but the exposure required is more and are thus not routinely used. Their speeds are denoted by A,B,C.
   b. *Fast films*: These have a larger grain size and the emulsion is on both sides. Their speeds are D-ultra speed, E- ekta speed and F- ultra ekta speed.
   c. *Hyper Speed G*: This is a 800-speed film that can halve the patient exposure without blurring image quality.

D. Packaging
   a. *Single film packet*.
   b. *Double film packet*: Two films are placed close to each other, when they are radiographed the second film serves as a duplicate.

E. Use, nonuse of Screens
   a. Screen films
      i. Sensitive to blue light, e.g. calcium tungstate Screens.
      ii. Sensitive to green light, e.g. Rare Earth Screens.
   b. Non-screen films.

F. Barrier envelopes
   a. With barrier envelopes: these ensure that there is no gross contamination in the dark room.
   b. Without barrier envelopes.

Composition of the X-ray Film (Fig. 9.1)

The X-ray film is made up of;

1. *Base*: is a transparent supporting material upon which the emulsion is coated. The dental film base is composed

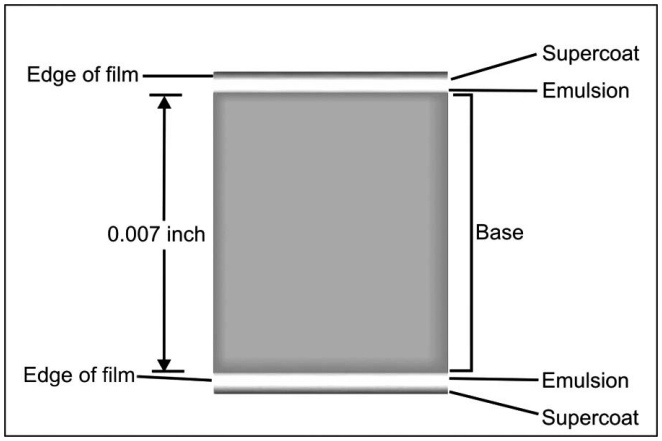


Fig. 9.1: Schematic diagram of the construction of a typical dental X-ray film. The film emulsion is coated on both the top and bottom surfaces of the polyethylene base; this allows for reduced exposure time and therefore a 'faster' film

of polyethylene terephthalate (a polyester) about 0.2 mm thick (0.007inches).The film base should,

i. Have the proper amount of flexibility to allow ease of handling.
ii. It should be translucent, casting no pattern on the resultant radiograph.
iii. For optimal viewing of the diagnostic detail the film base should have a bluish tint
iv. The base should be able to withstand exposure to processing solutions without distorting, heat, moisture and chemical exposure.

The film is known as a "safe film" if the base is made up of acetate polyester, because this is not easily inflammable.

2. *Substratum (sub coating)*: Is a thin adhesive material on both sides of the base, which ensures good adhesion between the sensitive emulsion and the film base.
3. *Emulsion*: Is coated on both sides of the base, containing silver bromide crystals suspended in gelatin. This is photo-sensitive to visible light and X-rays. The films intended to be exposed to X-rays are called Direct Exposure Films. All intraoral dental films are "Direct Exposure Films". It helps to record the radiographic image. The emulsion layer consists of:
   i. *Silver halide crystals*: These are photosensitive and composed primarily of silver bromide (80-99%) and to a lesser extent silver iodide crystals (1-10%). The mean diameter of the silver halide grain is about 0.70 to 0.75 mm. The presence of silver iodide crystals adds greatly to the sensitivity of the film emulsion, thereby reducing the radiation dose required to produce an adequate diagnostic image. The photosensitivity of the silver halide crystals is further increased by the incorporation of sulphur contamination during the manufacturing process.The silver halide crystals absorb radiation during X-ray exposure and store energy from the radiation.
   ii. *Gelatin matrix*: This supports the silver halide crystals, which are suspended in the gelatin framework applied to both sides of the supporting base. The gelatin is made from cattle bone and helps to keep the silver grains evenly dispersed. During processing the gelatin absorbs the processing solutions and helps to allow the chemicals to react with the halide grains.
4. *Super coat*: Is a protective, transparent, nonabrasive layer over the emulsion. This is an additional layer of gelatin which is applied to the surface to serve as a protective barrier and protects the film from damage by mechanical handling such as scratching, contamination and pressure from rollers during the automatic processing.

Intraoral film speed: This refers to the amount of radiation required to produce a radiograph of standard density.

Film speed, or sensitivity, is determined by the following:

- The size of the halide crystal.
- The thickness of the emulsion.
- The presence of special radiosensitive dyes.

Film speed determines the amount of radiation and exposure time required to produce an image on the film. For example, a fast film requires less radiation exposure because the film responds more quickly, this is due to the fact, that the silver halide crystals in the emulsion are larger. Thus larger the crystal faster the film. The disadvantage of using fast films is that though the amount of exposure to the patient is reduced, it is at the cost of the contrast quality which is reduced also.

An alphabetical classification is used to identify film speed. The films are given speed ratings from A speed (the slowest) to F speed (the fastest). Only D-speed and E-speed are used for intraoral radiography.

Intraoral Films

Intraoral films are available as (Fig. 9.2)
Periapical films: usually used to record crowns, roots and periapical areas related to the tooth.
No.0 for children. (22 × 35 m.m.)
No.1 for anterior adult projections. (24 × 40 m.m.)
No.2 for posterior adult projections. (31 × 41 m.m.)

Occlusal films: Used to show larger areas of the maxilla or mandible. The size of the film is 57 × 76 m.m.

Bite wing films: Used to record the crowns of maxillary and mandibular teeth in one film. These films have a paper tab projecting from the middle of the film (Fig. 9.3) on which the patient bites, to support the film.

They help in the detection of interproximal caries, visualize the alveolar crest and assessment of periodontal disease in more easier.
Size 0 for child (posterior) (22 × 35 m.m.)
Size 1 for child (anterior) (24 × 40 m.m.)
Size 2 for adult (posterior) (31 × 41 m.m.)
Size 3 for adult (anterior) (27 × 54 m.m.)

The intraoral films are available in plastic film packets. The film packet consists of; ((Figs 9.4 and 9.5):

1. An outer plastic wrapping, made of white paper or soft vinyl which is hermetically sealed, semistiff, moisture proof, light proof and clearly indicates which

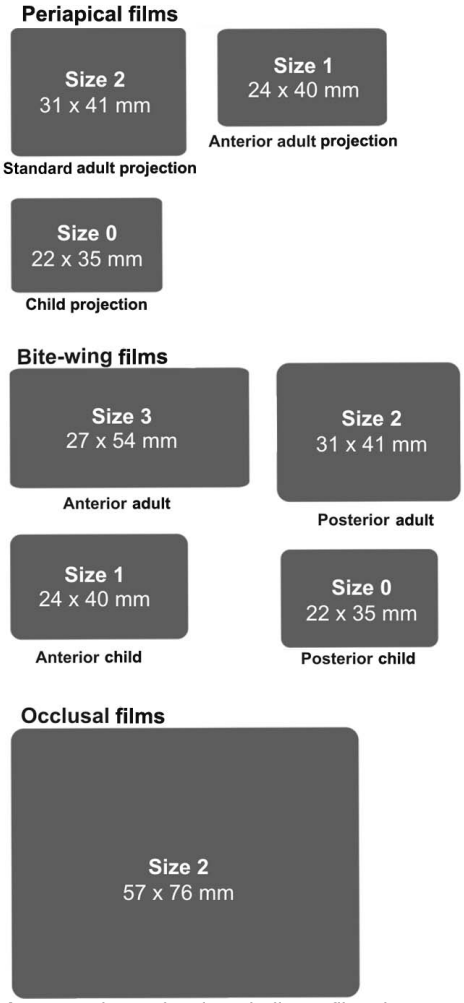


Fig. 9.2: These drawings indicate film sizes

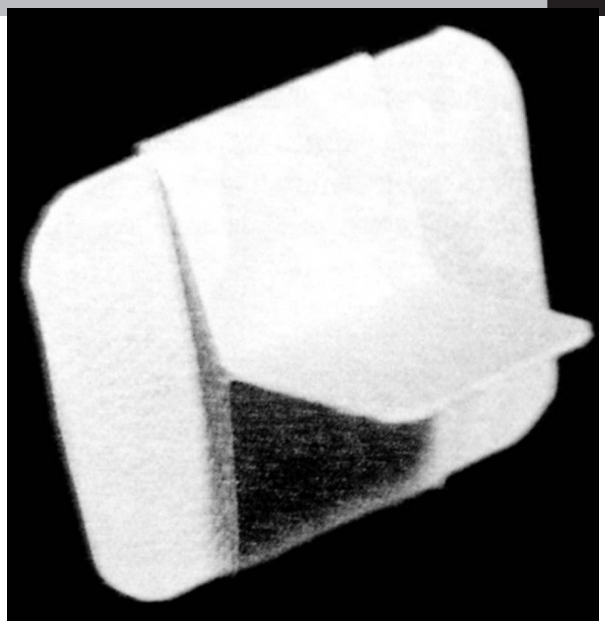


Fig. 9.3: Bite wing tab attached to the film

side of the film should be directed towards the X-ray tube. This outer wrapper serves to protect the film from exposure to light and saliva.

The outer wrapper of the film packet has two sides, tube side and label side.

The tube side of the plastic cover is solid white and bears an raised dot, this raised side should be placed towards the X-ray tube or the object to be radiographed. When inserted in the mouth, the edge carrying the dot

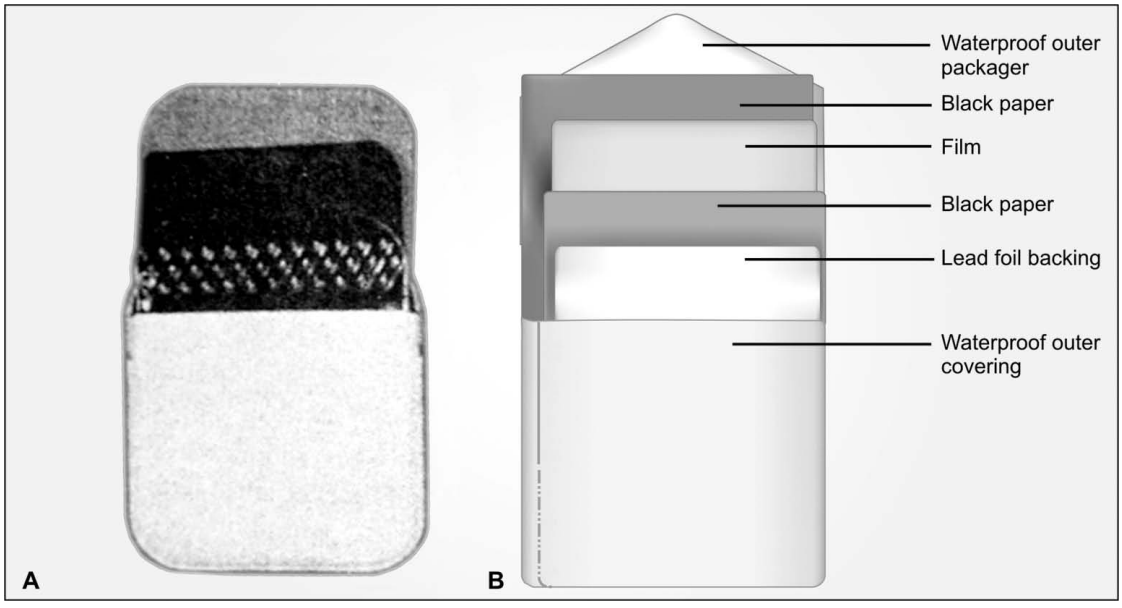


Fig. 9.4: A. Back of an opened dental film packet, **B.** Diagram of A

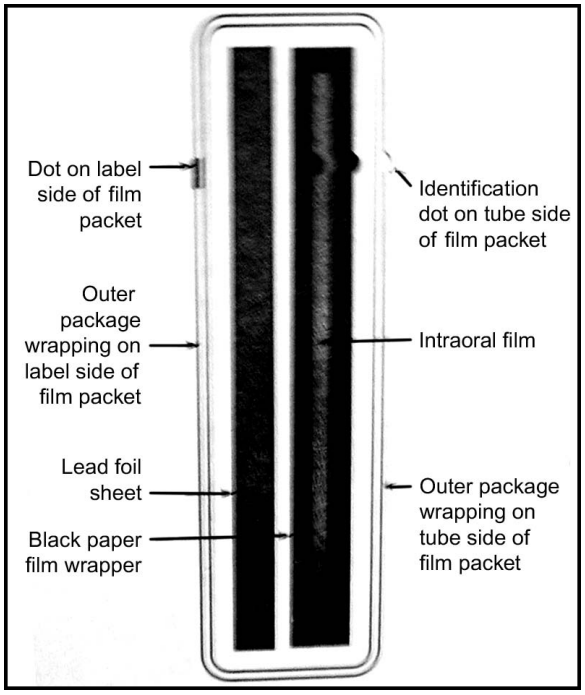


Fig. 9.5: Labeled film packet

should be placed at the incisive or occlusal margin of the tooth under consideration.

The dental X-ray film in the packet has a corresponding embossed dot on it which helps to identify the position of the film in relation to the patients mouth when mounting the radiograph.

The label side (Fig. 9.6) of the film packet has a flap that is used to open the film packet to remove the film prior to processing.The label side is color coded to identify films outside of the plastic packaging container, color codes are used to distinguish between one film and two film packets, and between speeds of the film. When placed in the mouth the color coded side must face the tongue. The following information is usually printed on the label side of the film:

- A circle or dot that corresponds with the raised identification dot on the film.
- The statement, "opposite side of the tube".
- The manufacturer's name.
- The film speed.
- The number of films enclosed.

The corners of the plastic packet and the enclosed film are rounded to avoid discomfort to the patient when the packet is introduced into the mouth.

2. A thin sheet of lead foil (Fig. 9.7) is placed in the plastic wrapper on the side of the film which is remote to the tooth under consideration and the X-ray tube. This foil

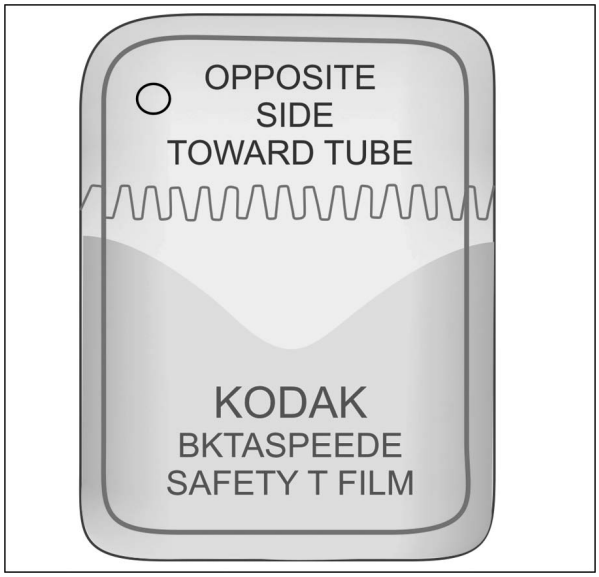


Fig. 9.6: The label side of a film packet

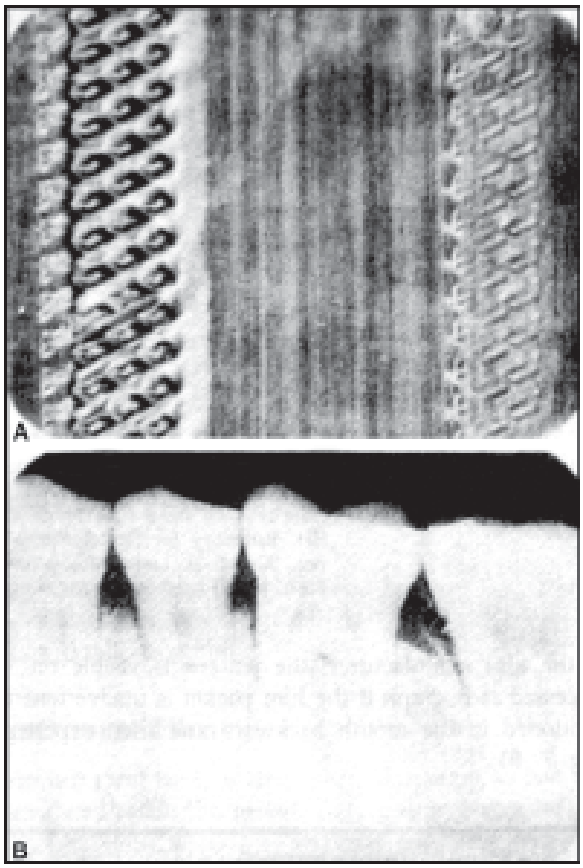


Fig. 9.7: A. The lead foil insert in the packet has a raised diamond packet across both ends. **B.** Radiograph showing the raised diamond pattern from the lead backing when the film is positioned backwards

absorbs most of the X-rays which pass through the film and prevent them from reaching the tongue and other oral tissues. It also absorbs the back scatter radiation and thus prevents fogging of the film which would otherwise cause a loss of important diagnostic detail.

A secondary function of the lead foil is to give sufficient but not excessive rigidity to the whole film packet.

If the film packet is placed reverse in the mouth , the shadow of the foil is seen on the resultant radiograph as tyre track marks or herring bone appearance, which is the embossed pattern placed on the lead foil by the manufacturer.

3. A sheet of black paper wraps the film to protect it from any light leak.
4. The X-ray film, which has rounded corners and an embossed raised dot for orientation.

The stabilization of these films may be done by various means:

1. Finger holding technique
2. Biting on the film or film tab.
3. Use of film holders.

Film holders

Film holders are of various types:

- Blade Type: (Fig. 9.8a)
  - i. Throat stick.
  - ii. Acrylic blade with slot.
  - iii. Snap-A-ray.
- Bite Block:
  - i. Styrofoam block.
  - ii. Snap-A-ray.
  - iii. Artery forceps with bite block.
- Positioning indicating device:
  - i. Rinn XCP (extension cone paralleling) with normal or rectangular collimator.
  - ii. Precision X-ray holder.

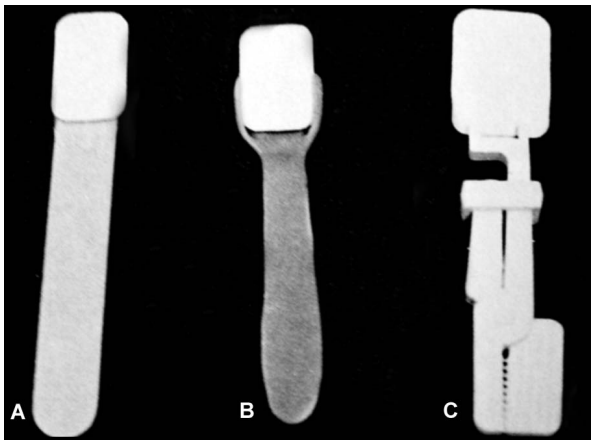


Fig. 9.8a: Examples of Blade type Film holders **A.** Disposable throat stick with film attached by cellophane tape. **B.** Acrylic blade with film inserted in a slot **C.** Plastic Snap-A-Ray film holder (or Emminex film holder)

Rinn Snap-A-Ray Film Holder (Fig. 9.8b)

This is a simple plastic film holder that can be used in both the anterior and posterior regions of the mouth. It does not have a film backing with it, thus the film may bend and cause image distortion. However, it is a very useful film holder, in that it can be used in various areas of the mouth with patients who cannot tolerate a film backing.

This film holder is particularly useful for the following projections:

- Mandibular premolars and molars: since these teeth have almost perpendicular roots, the film is positioned in close approximation to the teeth. However, this film holder does not have an alignment extension to aid the operator in obtaining the proper vertical and horizontal angulations.
- Maxillary and mandibular third molar projections.
- Patient's with hypersensitive gag reflexes.
- Children and edentulous projections.
- Endodontic projections.

Fitzgerald Hemostat (Fig. 9.9)

This hemostat was specially designed by Dr Gorden Fitzgerald of the University of California. This hemostat differs from the usual surgical hemostat in that the serrations on the beak run length wise rather than across the beak. The hemostat comes complete with a rubber bite block and suitable metal film backings. It is especially useful in patients who have a limited degree of mouth opening.

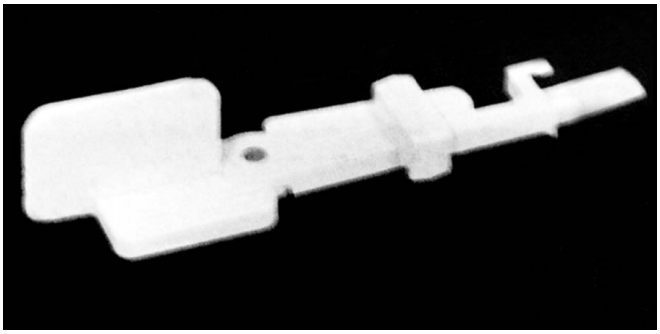


Fig. 9.8b: Snap-A-ray intra oral film holder (or Emminex film holder)

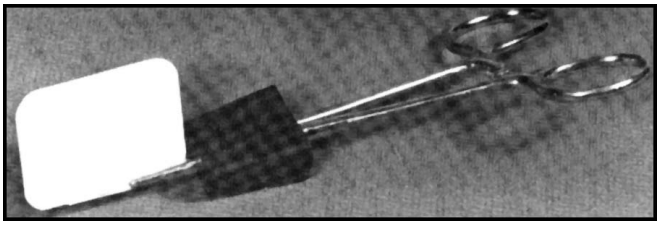


Fig. 9.9: Hemostat and rubber bite block

The patient retains the forceps within the mouth by biting against the rubber bite block with his maxillary and mandibular incisors.

After the patient bites on the rubber bite block, the film and the film backing are rotated until it is parallel to the long axis of the teeth being radiographed. The film should be placed against the palate, and usually parallel to the midline.

The beam is directed through the apices of the teeth at right angles to the teeth. The vertical angle is determined by the position of the hemostat handles. For the horizontal angle, the X-ray beam is directed through the interproximal spaces of the teeth.

Bite Blocks (Fig. 9.10)

Bite blocks are used for the anterior (mandibular and maxillary) and mandibular premolars. In the anterior projection, the film is inserted into the slot in the small end of the wooden bite block and the patient bites on the large end of the film block. In case of the mandibular anterior and premolar, the film is inserted in the slot in the large end of the block and the patient bites on the small end of the block.

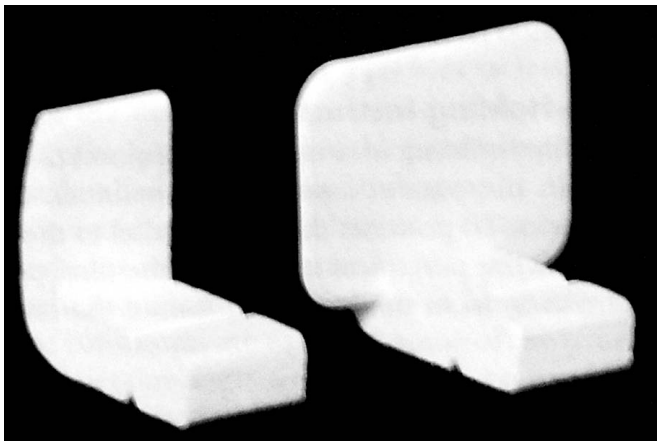


Fig. 9.10: Disposable stabe bite blocks

When using this film holder care should be taken in positioning the patient; the sagittal plane of the head should be perpendicular to the floor and the occlusal planes of the maxillary and mandibular teeth should be parallel to the floor, when taking radiographs of the maxillary and mandibular teeth respectively.

Rinn XCP Instruments (Fig. 9.11)

This is a set of two instruments, an anterior and a posterior instrument, which were designed by Dr William J Updegrave of the School of Dentistry, Temple University at Philadelphia. Each instrument consists of three parts:

1. *Anterior and posterior bite blocks*: These are designed to retain the film packet by means of tension created by a semi-flexible plastic backing.
2. *Indicator rod*: These are made of stainless steel and are used to align the X-ray cone with the film. There is an anterior rod off set and a posterior right angled rod designed to insert into the receptacle holes of the respective bite blocks.
3. *Locator ring*: (Figs 9.12 and 9.13) They are made for sliding into the rod to establish alignment of the cone and rectangular shaped extension cone with the film. This also prevents "cone-cutting".

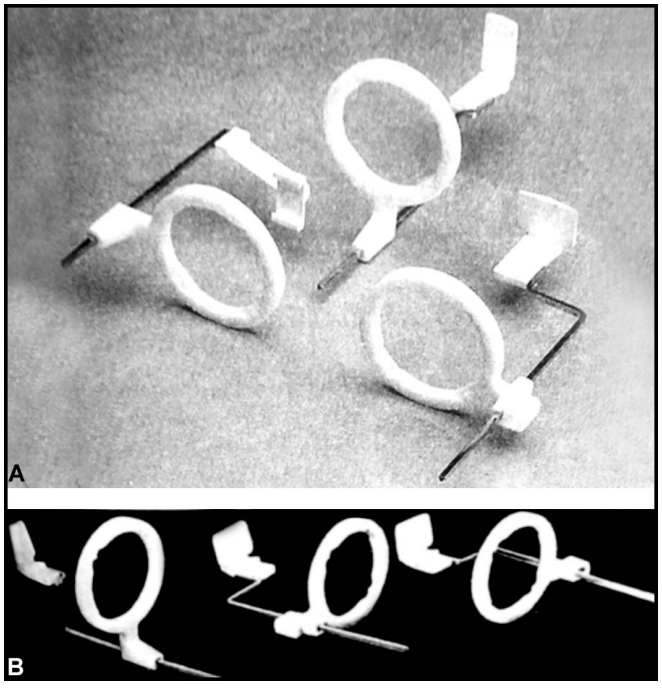


Fig. 9.11: A. Rinn XCP instruments. **B.** Rinn BAI instruments

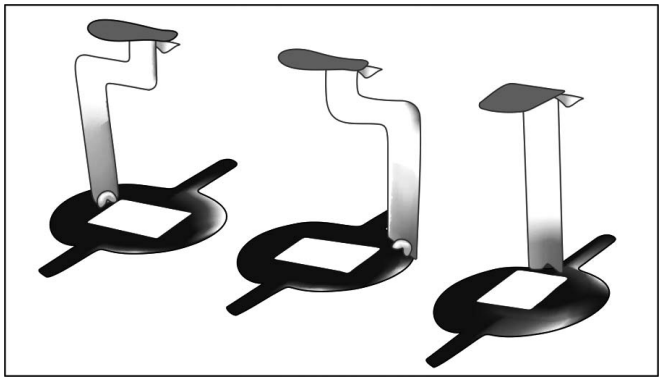


Fig. 9.12: Precision film holders restrict the size of the X-ray beam

The Rinn XCP instruments have been modified to include a rectangular shaped locator ring which can be rotated on it's own axis. This modification helps to accomplish two things:

i. Reduces exposure to the patient.
ii. Simplifies cone and film alignment.

Advantages of Film Holders

- It allows the film to be placed parallel to the long axis of the teeth, maintaining a flat plane at all times, and retaining the film in position until it is properly exposed.

Disadvantages of Film Holders

- Due to the presence of the bite block resting upon the teeth, the film may not extend far enough beyond the apical region to allow any latitude for examination of the apical tissues and structures.
- The mouth closing over the block prevents the operator from checking the position of the film in the mouth.
- It is difficult to angulate the tube to meet abnormal conditions. In many cases exposures with the use of film holders results in distortions of the teeth.

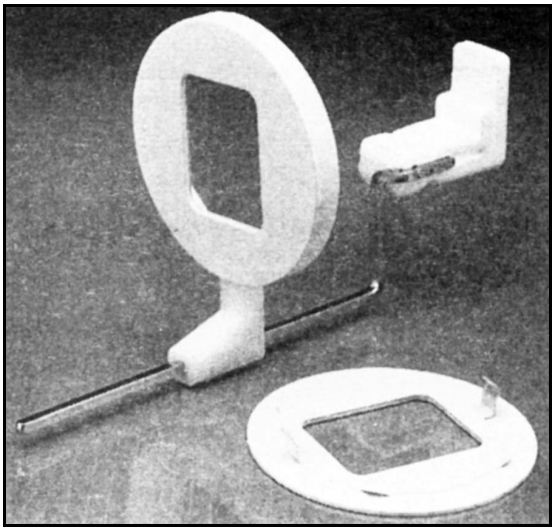


Fig. 9.13: The Rinn Snap-on collimator can be used to reduce the amount of radiation a patient recieves

Sterilization and Disinfection of Film Holding Devices

The holders should be mechanically cleaned and well rinsed in running tap water to remove saliva before sterilizing.

The Plastic XCP can only be steam autoclaved.

The Precision may be steam autoclaved or subjected to dry-heat sterilization. The bite blocks used with the precision instruments are disposable and should be discarded.

After sterilization, the instruments should be placed in 16" × 10 ¾" plastic bags (with new disposable bite blocks in the case of Precision instruments) for storage and subsequent transport to the radiography area. The instruments must be placed in the bag with clean, gloved hands, working on a clean, disinfected surface.

The instruments to be taken to the radiography are in the given bags, and after using them they should be replaced in the same bag and brought back to the cleaning/sterilizing area.

Extraoral Films

Extraoral films are those that are placed outside the mouth during X-ray exposure. These are used to examine large areas of the skull and jaws. These films are of two types: Non- Screen Films and Screen Films.

Both are available in various sizes
4 ¾''× 6 ½''
5'' × 7''
6 ½'' × 8 ½''
8'' × 10''
10'' × 12''

Unlike intraoral films, extraoral films are designed to be used outside the mouth and therefore are not enclosed in moisture proof packets. Extraoral films commonly used in dentistry are of the sizes 5'' × 7'', 8" × 10'', as well as panoramic, 5'' × 12'' and 6" × 12''. Extra oral films are boxed in quantites of 50 or 100 films. Some manufacturers separate each piece of film with protective paper. Boxes of extraoral film are labeled with the type of film, film size, the total number of films enclosed and the expiration date.

The films are usually placed in a film cassette, with or without intensifying screens.

High contrast medium speed films are suitable for panoramic and skull radiography.

Faster films which provide less image detail are used for panoramic radiography.

Films which provide less contrast and a wider latitude thus producing a wide range of densities are used in cephalometric radiography where soft tissue detail is required.

Non-screen films: These are used without the intensifying screens. The emulsion is sensitive to direct X-ray exposure rather than fluorescent light. These films are much slower and therefore require a longer exposure time but the detail of the image obtained on using these films are much sharper. Thses films are not recommended for dental use.

Screen films: These films are used in combination with intensifying screens, that emit visible light. These screens are placed in the film cassette, on either side of the film and are held under pressure in a rigid manner, so that the fluorescent layers of the screen and the emulsion of the film are pressed together closely. Poor contact produces a blurring of the image on the radiograph. When the cassette is exposed to X-rays, the screens convert the X-ray energy into light, which in turn exposes the screen film. Screen film is sensitive to fluorescent light rather than direct x-radiation.

Screen films are of two types, blue light sensitive (Kodak X-Omat and Ektamat films), and the other being green light sensitive (Kodak Ortho and T-Mat films). The Green light sensitive films are those used with the rare earth intensifying screens, and these are two or more times faster and provide sufficient clarity for most diagnostic tasks. These films (T-Mat) have tubular shaped silver halide grains which are oriented with their flat faces to the radiation source, thus providing a larger cross-section and resulting in increased speed without loss of sharpness. Green sensitizing dyes are also added to increase the light gathering capability and to reduce the cross over of light from the phosphorous layer of one side of the intensifying screen to the film emulsion on the other side of the film. The combined effect increases the speed and sharpness of the film. These are used for skull, cephalometric and panoramic radiography.

It is important to use the right screen film combination so that the emission and absorption characteristics of the screen and film are matched.

Extraoral film equipment: These films are used in combination with cassettes and intensifying screens (where applicable).

Cassette (Figs 9.14 and 9.15)

This is a special device that is used to hold the extraoral film and the intensifying screens. Cassettes are available in a variety of sizes that correspond to the film and screen sizes. A cassette may be flexible or rigid, most cassettes are rigid except for the panoramic cassette, which may be flexible.

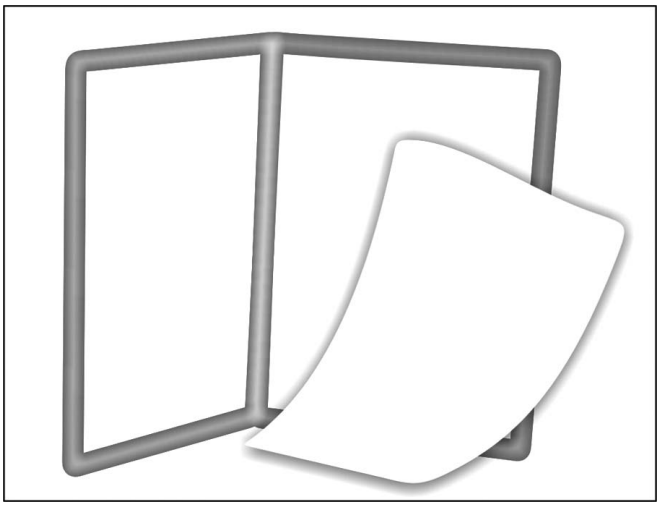


Fig. 9.14: Cassette for holding 8 x 10 inch film. When the cassette is closed, film is supported between two intensifying screens

A rigid cassette is more expensive, but it also lasts longer. A rigid cassette protects the screens from damage.

The film fits the rigid cassette exactly and cannot be loaded incorrectly, however, to load the flexible cassette properly, the film must be placed between the two screens and pushed to the end of the cassettes.

Both rigid and flexible cassettes must be light–tight, not only to protect the extraoral film from exposure but also to

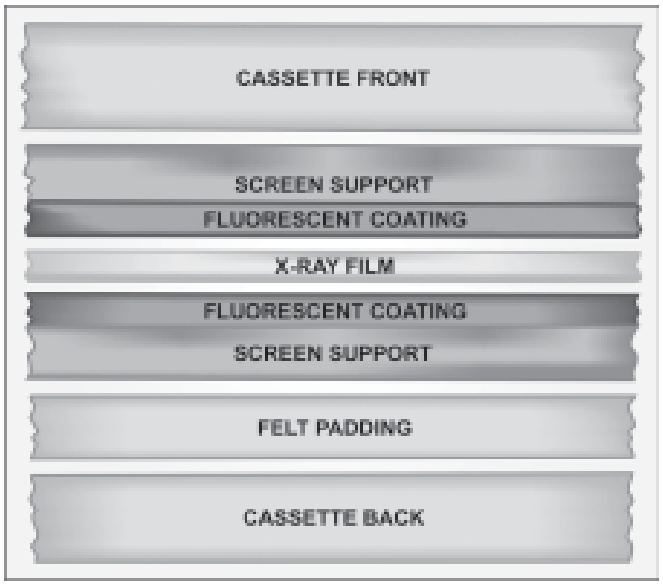


Fig. 9.15: Diagram showing cross-section of components of a loaded cassette. In use all the elements should be in uniform contact

hold the intensifying screens in perfect contact with the extraoral film. This contact is critical, as lack of proper contact results in a loss of image sharpness.

A rigid cassette is like a book like container consisting of two aluminum or bakelite leaves which open and close on hinges. The front cover lid is placed so that it faces the tube head and is usually constructed of plastic or of low density metal and offers little resistance to the passage of the ray. The back plate is constructed of heavy metal and lined with lead to absorb X-rays which pass through the enclosed film and reduce scatter radiation. The intensifying screens are installed inside the front and back covers of the cassette. The film is positioned between the two intensifying screens. Each screen exposes one side of the film. The cassette is loaded and unloaded in the dark room.

There are many holders and contrivances available to retain the cassette in a stable position and are all mounted, either in conjunction with a potter bucky diaphragm or on a special material frame work.

The cassette must be marked to orient the finished radiograph, a metal letter 'L' or 'R' is attached to the front cover of the cassette to indicate the patient's left or right side respectively.

Intensifying Screen

Intensifying screen (Fig. 9.16) is a device that transfers X-ray energy into visible light; the visible light, in turn exposes the screen film. These screens intensify the effect of X-rays on the film, thus less radiation is required to expose a screen film, and thus the patient is exposed to less radiation.

The action of radiation on photographic film is supplemented by means of special screens which intensify the action of X-rays. Some materials are able to absorb X-rays and re-emit the energy in form of visible light photons. The amount of light emitted is strictly proportional to the amount of X-ray energy absorbed which in turn is proportional to the X-ray exposure to which the screen is subjected. It is then the sum effect of X-rays and visible light emitted by the screens that exposes the X-ray film. Such a combination of X-ray film with an intensifying screen results in an image receptor system ten to sixty times more sensitive to X-rays than the film alone. Thus the duration of exposure is reduced, the contrast improved and radiation back scatter minimized.

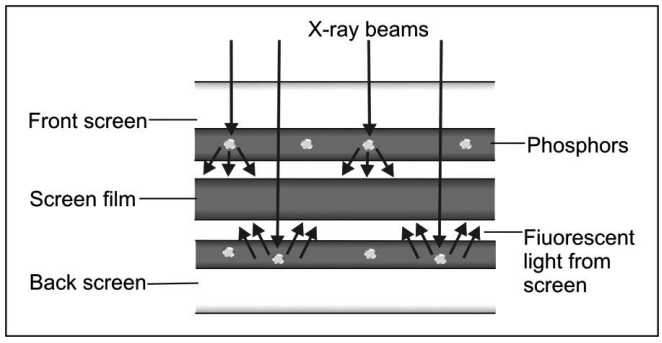


Fig. 9.16: Phosphors in the intensifying screen emit visible light when hit by X-ray photons. Multiple visible light photons then strike and expose the film

In extraoral radiography, a screen film is sandwiched between the two intensifying screens of matching size and secured in a cassette.

An intensifying screen is a smooth plastic sheet coated with minute fluorescent crystals known as phosphors. When exposed to X-rays, the phosphors fluoresce and emit visible light in the blue or green spectrum, the emitted light then exposes the film.

Composition

a. *Base*: Made of either a stiff sheet of cardboard or polyester plastic material (like the one used for the base of the radiographic film). It is about 0.25 mm thick. The base is the supporting component of the screen.
b. *Reflecting layer*: This is a thin layer of white material (i.e. magnesium oxide or titanium dioxide) between the base and the luminiscent layer. It serves to redirect the film a large fraction of the emitted visible light which is moving away from the film and which would therefore otherwise be lost. Thus, it increases the sensitivity but some degree of unsharpness is created because of divergence of light reflected back to the film.
c. *Phosphor layer*: This layer consists of a light sensitive phosphor crystals suspended in a plastic material.
When these crystals are struck by photons they fluoresce, that is, they emit visible light photons that expose the X-ray film. Even a single X-ray photon absorbed in an intensifying screen generates many light photons leading to increased film exposure. The speed of the screens increases as the crystal size increases but the overall image quality may be degraded. Types of phosphor used in dental screens are:
   i. Crystalline Calcium Tungstate, that fluoresces in the blue portion of the spectrum. Conventional screens (Kodak X-Omatic Regular screens) are used with blue sensitive films.
   ii. Rare earth intensifying screens using terbium-activated gadolinium oxysulphide and thelium-activated lanthanum oxybromide, which fluoresce in the green portion of the spectrum.

The newer rare earth screens have phosphors that emit green light. The term 'rare earth' is used because it is difficult and expensive to separate these elements from earth and from each other and not because these elements are rare. Rare earth intensifying screens are four times more efficient than calcium screens and are considered faster, and thus less exposure is required when these rare earth screens are used. Rare earth screens (Kodak Lanex Regular and Medium screens) are designed for use with green sensitive films.

d. *Coat*: This layer protects the phosphor layer from mechanical insult such as abrasion, scratching, etc. It is important to keep the intensifying screens clean, because any debris, spots which are opaque to visible light or scratches will result in light (under exposed) spots on the resultant radiograph.

Effect of the Screens

1. *Unsharpness*: There are three types of screens available in the market:
   i. High definition.
   ii. Normal.
   iii. High speed.

   The manufacturer controls the screen thickness, crystal size and the amount of dye included in order to produce the optimum combination of intensification factor and screen unsharpness. The range of unsharpness produced by the screens varies from 0.15 mm for high definition to 0.45 mm for high speed screen.

   The use of the screen also produces an additional amount of image blurring over that would occur if no screen is used. This extra blurring is greater for screens with a higher intensification factor.

   But, this fact is compensated for by the reduction in X-ray exposure so that the other type of unsharpness is reduced. Thus the overall result is that the total unsharpness is less when screens are used than when they are not used.
2. *Mottle*: This consists of faint irregular pattern of density variations which are not present in the X-ray beam.
   a. *Screen mottle*: Nonuniformity in the fluorescent layer may show up on the radiograph since the intensification factor will vary over the surface of the screen. This effect is not as marked in the newer screens.
   b. *Quantum mottle*: This is related to the actual number of X-ray photons which arrive at the cassette. With the advent of fast films, the actual number of X-ray photons which reach the cassette and form an image pattern on the radiograph are comparatively small. Emission of X-rays is a random process and so uneven is the primary beam, that the average number of X-ray photons directed at any part of the screens will not be the same. Hence, there is a variation in the X-ray intensity over the surface of the screen and it becomes apparent on the film. This is called Quantum Mottle.

      The use of fast films in combination with the screens reduces the exposure to the patient.

Care and Use of Screen

1. There should be no gap between the screen and the film, so as to avoid excessive blurring of the image because of greater area of the film over which light can spread.
2. The cassette after use may become buckled or bent, and then it is difficult even for the felt lining in the cassette to help maintain close contact between the screen and the film.
3. Scratches, dust or grease will also prevent light photons passing from the screen to the film and thus, will show a pattern on the film. Thus, this should be prevented.

Lead intensifying screens: are used only with high kV, radiography, i.e. with 250kV X-rays or cobalt 60 gamma rays. Their intensification factor is quite small, about 2-3, and their mode of action is completely different from that of 'salt screens'.

The absorption of X-rays by the screen results in production of fast-moving electrons (photo-electric or compton) and it is the release of these electrons which—in the case of lead screens—produce the latent image and intensification.

It is important to note that metal intensifying screens can only be used at kV, sufficiently high to produce electrons capable of leaving the screen and reaching the emulsion. As with 'salt screens', lead screens are used in pairs but they are considerably thinner. The front screen is usually about 0.1 mm (0.004 in) and the back screen 0.15 mm (0.006 in) thick.

Because of their thinness lead screens introduce no additional screen blurring: neither do they suffer from reciprocity law failure.

DUPLICATING FILM

A duplicate radiograph is one that is identical to the original. It is useful when the patient is referred to a specialist, for insurance claims and as teaching aids. A special duplicating film is required to make duplicate radiographs.

A duplicating film is a type of photographic film that is used to make an identical copy of an intraoral and extraoral radiograph, but unlike the radiographs, this duplicating film is used only in a dark room setting and is not exposed to X-rays.

The duplicating film has emulsion only on one side only. The emulsion side of the film appears shiny, whereas the side without the emulsion appears dull. The emulsion side of the film must contact the radiograph during duplication process.

Radiographic duplicating films are available in periapical sizes as well as in 5 × 12″ and 8 × 10″ sheets.

A small photographic printer, can be used, by replacing the bulb with an ultra violet bulb, may be used as the light source for duplicating.

Film Protection and Storage

- Film is adversely affected by heat, humidity and radiation.
- To prevent film fog, unexposed, unprocessed film must be kept in a cool, dry place.
- The optimum temperature for film storage ranges from, 50° to 70°F.
- Optimum relative humidity level ranges from 30% to 50%.
- Film must be stored in areas that are adequately shielded from sources of radiation and should not be stored in areas where patients are exposed to x-radiation.
- To prevent film fog, lead-lined or radiation-resistant film dispensers and storage boxes are ideal.
- All dental X-ray film has a limited shelf life. Each box or container of film is clearly labeled with an expiration date.
- The 'first in, first out' rule of thumb should be applied to film use, the oldest film in stock always used before any new film.

Grids

These are devices which reduce the amount of scattered radiation reaching the film whilst still allowing the patterns containing the primary beams to reach the film.

The grid prevents the scattered radiation from reaching the film. Scattered radiation causes fog and reduces contrast of the film. This is because the scattered photon has lower energy than the primary photon and therefore is less penetrating and thus causes fogging of the film. (Figs 9.17 and 9.18)

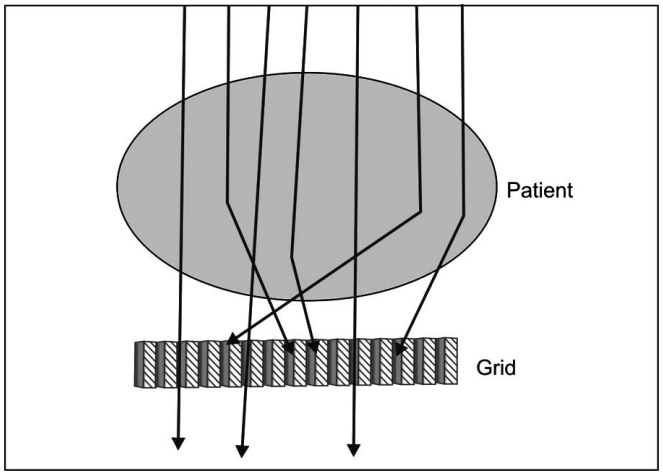


Fig. 9.17: Obliquely moving scattered radiation is stopped by the grid, whilst the forward moving primary photons pass to the film

Types of Grids

A. Focused grids and non focused grids.
B. Stationary grids and moving grids.

Stationary Grids

As the name suggests, the grid is stationary and does not move. The presence of a grid between an object and the film causes the images of the radiopaque absorbing material to be projected onto the film.

1. *The linear grid*: The strips of lead used are placed strictly parallel to each other. In this, the primary radiations travelling radially from the X-ray tube focal spot to the film will encounter the grid obliquely. Thus the grid lines appear wider. At a sufficiently large distance from the

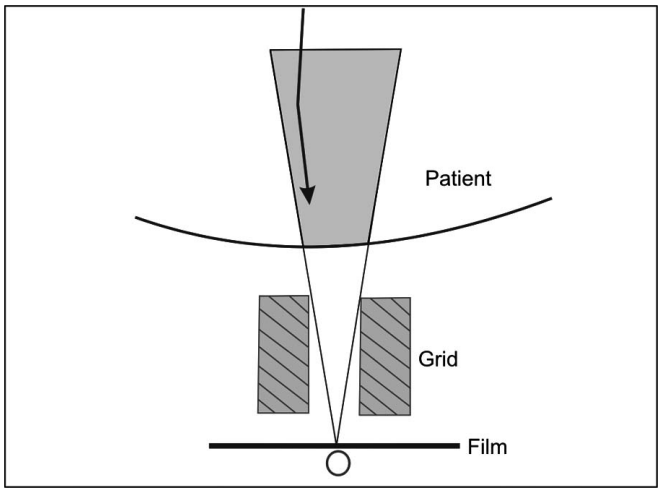


Fig. 9.18: Scattered radiation produced within the shaded region of the patient and moving towards O is able to reach O unimpeded by the grid

center of the beam, a complete cut off of the primary radiation may occur. For all practical purposes the central beam should be in a plane parallel with the grid lines. This arrangement of the elements of the linear grid will eliminate the absorption of the more divergent primary photons at the margins of an X-ray beam, where their direction does not coincide with the alignment of the perpendicular lead strips in the grid.

2. *The focused grid*: In this grid the strips of lead are angled progressively from the center to the edge so that inter spaces point at the focal spot, thus their direction coincides with the direction of the path of diverging photons in the primary X-ray beam, thereby accommodating their passage through the grid. This helps to prevent the primary cut off.
3. *The pseudo-focused grid*: In this grid the height of the strips is reduced progressively from the center resulting in a reduced grid ratio from the center to the edge. (Fig. 9.19)
4. *The crossed grid*: The linear grids are placed mutually at right angles so that even a small amount of scattered radiation gets blocked.

Moving Grid (Potter Bucky Grid)

In this the grid is moved side ways across the film during exposure. This leads to the blurring out of the shadows of grid strips, thus they are not visible on the film. Thus the image of the radiopaque grid lines on the film can be deleted by mechanically moving the grid in a direction of 90° to the grid lines, (but not the object) during exposure. This results in evening (blurring) out the radiolucent lines and resulting in a more uniform exposure. It does not interfere with the absorption of scattered photons.

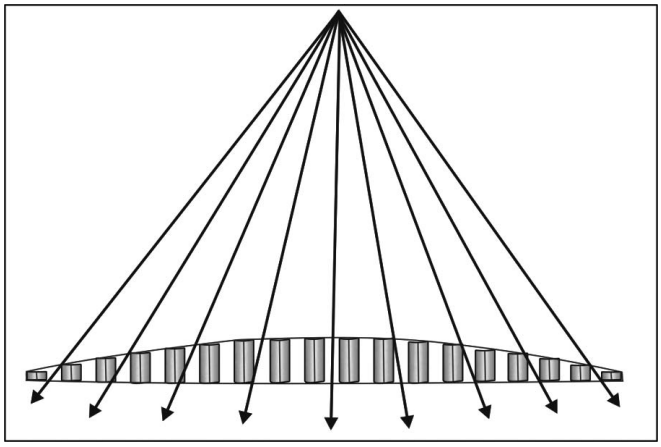


Fig. 9.19: A psuedo focused grid

Composition

It is composed of a series of long parallel strips of an opaque material (usually lead) held apart and parallel to each other by an X-ray transparent interspace material (usually plastic). (Figs 9.20 and 9.21)

Working

The grid is placed between the patient's head and the film. During exposure, the grid permits the passage of the X-ray beam between the lead strips.

When some of the X-rays interact with the patient's tissues, scatter radiation is produced; this scatter radiation is then directed at the grid and film at an angle. As a result, scatter radiation is absorbed by the lead strips and does not reach the surface of the film to cause film fog.

The scattered radiation moves obliquely because of the change in direction which occurs in the scattering process. The majority of this radiation (scattered radiation) is stopped by the lead of the grid and hence it does not reach the film, on the other hand the majority of the primary radiation which is moving forward will pass through the interspace and reach the film upon which it will therefore impress the X-ray pattern.

The presence of the grid is usually able to remove as much as 80% - 90% of the scattered radiation. This largely helps to improve the contrast. The contrast improvement factor (K) is calculated as;

$$K = \frac{\text{X-ray contrast with grid}}{\text{X-ray contrast without grid}}$$

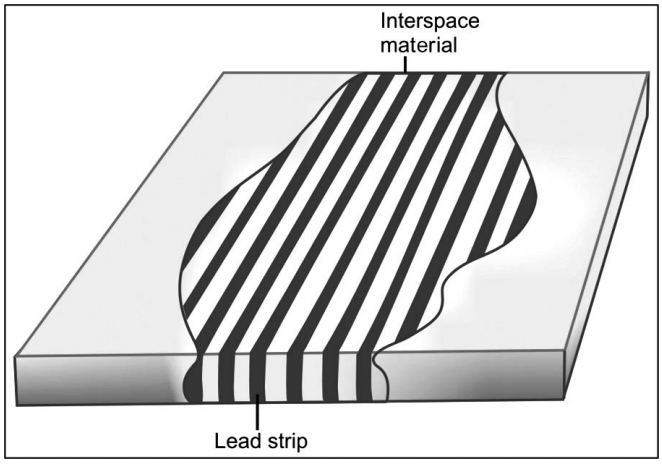


Fig. 9.20: A grid showing the long, thin parallel lead strips separated by wider interspace material. The whole is enclosed in a metal outer covering

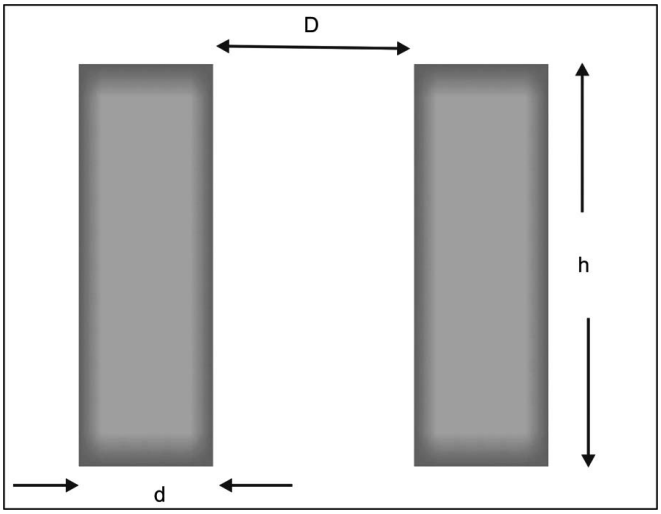


Fig. 9.21: The controlling dimensions of a grid are the width (d) of the lead strips, the width (D) of the interspace, and the height (h) of the strips

Larger the value of K, better is the contrast. Grids usually have K equal to 1.5 to 3.5.

It is important to note that the grid also removes some primary radiation along with scattered radiation. Those primary photons which hit the lead strips are absorbed and only those primary photons incident upon the inter space material is transmitted to the film. This creates an overall pattern of thin parallel white (clear) lines on the film called "grid lines".

These are seen when fixed grids are used.

The closer together the grid lines on the film, however, the less objectional they become. In general, grids with 80 or more line pairs per inch do not show objectional grid lines. The ratio of the grid thickness to the width of the radiolucent spacer is known as "grid ratio". (Fig. 9.22) The higher the grid ratio, the more effectively will the scattered radiation be removed from the X-ray beam. In general, grids with a grid ratio of 8 to 10 are preferred.

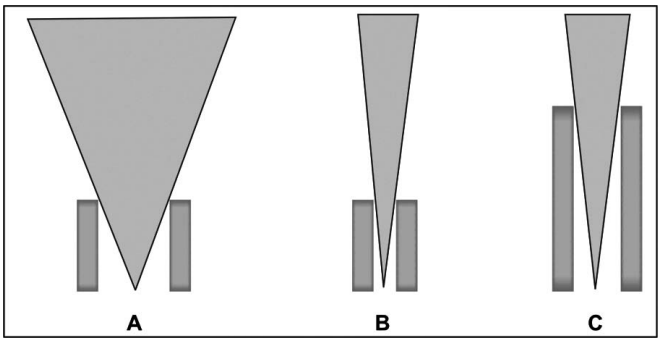


Fig. 9.22: Grid A has a smaller ratio than grids B and C which have the same ratio. The volume of the patient from which scattered radiation can reach the film decreases as the grid ratio increases and is the same for grids of the same grid ratio (B and C)

Advantages of a Grid

- Scattered radiation exiting an irradiated object may be largely removed or reduced from the beam reaching the film by placing an X-ray grid between the object and the film. This helps to reduce film fog and increase radiographic (film) contrast.
- Some clinicians have found it useful to superimpose fine wire grids when exposing radiographs to aid in the measurement of relative bone height. Typically the grid form 1mm squares, which appear as fine radiopaque lines on the resultant radiograph, that allow the quantitative measurement of the position of the alveolar bone with respect to the dentition. The procedure is particularly useful in evaluating osseous changes in radiographs made at different times with a reproducible positioning technique.

Disadvantage of a Grid

- The exposure required to produce a radiograph when a grid is used approximately doubles compared to that used in the absence of a grid. This is to compensate for the presence of lead strips in the grid, an increased exposure time must be used to expose a film. Because of this increase in exposure time, a grid should be used only when improved image quality and high contrast are necessary.

Filtration (Fig. 9.23)

This involves removal of unwanted radiation whilst leaving the wanted radiation undiminished.

Radiation emitted by an X-ray tube is made up of photons of many different energies. The maximum photon energy depends only upon the kilovoltage used to generate the radiation. Whilst the minimum energy depends upon the

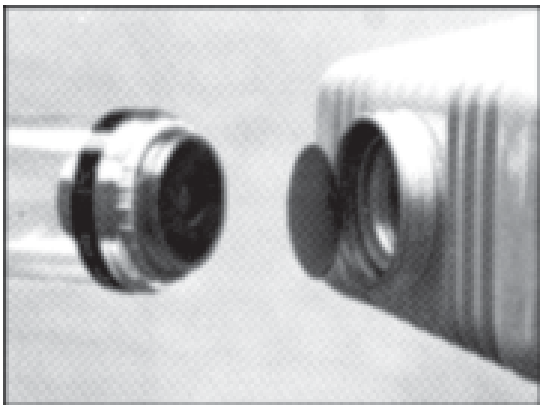


Fig. 9.23: Aluminum disks are placed between the collimator and tube head seal for added filtration

nature and thickness of the material of the wall of the X-ray tube. Because of their different energies, the photons have different penetrating powers. When the beam of radiation is incident upon the patient, the bulk of the low energy photons is absorbed in the superficial layers, which produce unwanted effects. Thus, these low energy radiations must be removed by a process called Filtration.

Filtration of a beam is accomplished by

i. *Inherent filtration*: The primary beam of radiation passes through the glass wall of the tube, a layer of oil and the aperture window. As it passes through these components of the tube, a certain amount of filtration takes place, which is called Inherent Filtration.
   This filtration is usually not sufficient and additional filtration is required.
ii. *Additional filtration*: Additional materials are placed in the path of the primary beam to aid in further filtration.

Total filtration is the sum of Inherent Filtration plus the Added Filtration.

Requirements of Filter Material

i. It should be able to discriminate against the lower energy photons.
ii. The material should not have an absorption 'edge' at an energy close to the energies of the photons that are desired to be used.
iii. The thickness of the material must not be too small because in such cases, due to irregularities in thickness, the beam thus produced would be nonuniform.

Materials used for Filtration

The materials used may vary depending upon whether the beam is of high or low energy and therefore depending upon the generating voltage used. The generally accepted X-ray range for the materials used is:

i.	30 kV - 120 kV	Aluminum (most commonly used)
ii.	100 kV - 250 kV	Copper (with appropriate backing)
iii.	200 kV - 600 kV	Tin (with appropriate backing)
iv.	600 kV - 2 mV	Lead (with appropriate backing)
v.	Above 2 mV	None

The aluminum filter is the one, most commonly used. The recommended Total Filtration must be equal to

1.5 mm of aluminum for up to 70 kVp
2.5 mm of aluminum for all higher voltages.

Effects of Filtration

1. It removes unwanted radiations and hardens the beam.
2. If progressively thick layers of the filter material are introduced and the effects studied, it is found that initially there is a substantial increase in the quality accompanied by a substantial reduction in the beam intensity. Thus, there is a certain optimum thickness beyond which no further hardening occurs.
3. It reduces unnecessary less penetrating radiation (skin dose) to the patient, which has no diagnostic value.

Patient exposure may be further reduced by removing both low and high energy X-ray photons from the beam, leaving the mid range energy photons to expose the film. X-ray energies most effective in producing the image are between 35 keV and 55 keV.

The material used are rare earth elements like samarium, erbium, yttrium, niobium, gemdolium, terbium activated gadolinium oxysulfide and thulium activated lanthanum oxybromide.

The use of these in combination with aluminum will reduce the exposure by 20% - 80% more than when only aluminum is used.

But there is 50% increase in the exposure time with decrease in contrast, sharpness and resolution of the resultant image.

Collimation (Figs 9.24 and 9.25)

Is the method by which one can control the size and shape of the X-ray beam.

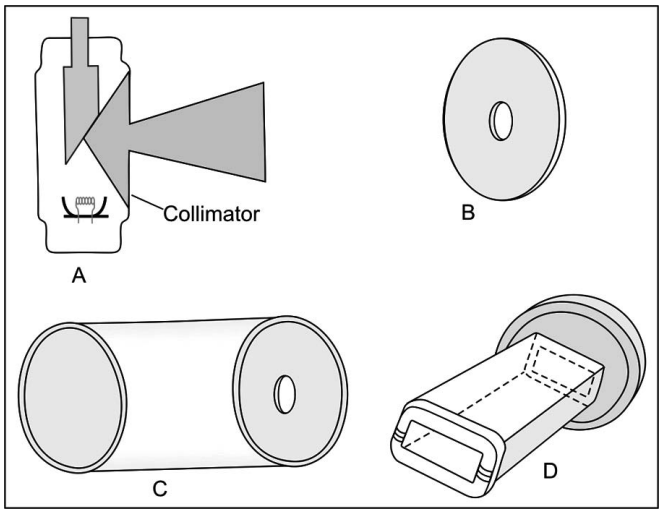


Fig. 9.24: A. Collimation of an X-ray beam (shown in color) is achieved by restricting it's useful size. **B.** Diaphragm Collimator. **C.** Tubular Collimator. **D.** Rectangular collimator

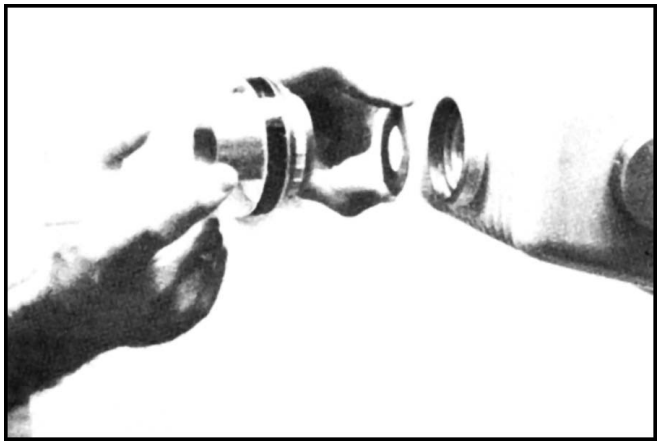


Fig. 9.25a: The hole in the collimator may be round

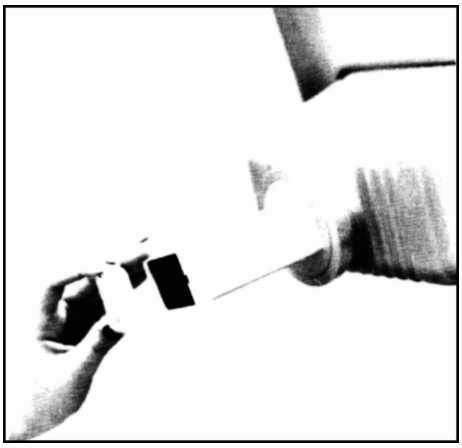


Fig. 9.25b: The rectangular metal collimator to restrict X-ray beam to the size of the periapical film

When an X-ray beam is directed towards a patient, most of it is absorbed by the overlying tissues and a very small portion of the beam actually reaches the film to form the image. Some of the absorbed radiation is further given out in all directions (compton effect). Thus, it may be observed that these radiations serve no useful purpose for the formation of the image on the film, but, instead add to the film fog. Thus it is important to keep the size and shape of the beam just adequate to irradiate only the required area and no more. This method to control the size and shape of the primary beam is called Collimation. This is achieved by placing a radiopaque barrier containing an aperture in the path of the beam. This reduces patient exposure and also ensures better film image quality.

Types of Collimators

They may be fixed type or adjustable type:

1. *Diaphragm collimator*: It consists of a thick plate of radiopaque material (usually lead) with an aperture or an opening in it. The device is usually placed over the port in the X-ray head through which the X-ray beam emerges. The aperture may be of different size and shape as per the requirement.
2. *Tubular collimator*: It is tube lined with or constructed of radiopaque material.

   A combination of tubular and diaphragm collimator can be used in which case, one end of the tube is in conjunction with the diaphragm collimator, which covers the X-ray port. This combination, also helps to reduce the penumbra at the periphery of the image. The longer the tube used, smaller is the penumbra.
3. *Rectangular collimator*: These collimators limit the size, just larger than the size of the X-ray film. This rectangular collimation can also be incorporated in a film holding device.
4. Slit collimator used in OPG machines.

BIBLIOGRAPHY

1. Frommer HH. Image formation Image Receptors in Radiology for Dental Auxillaries, 6th ed. St. Louis, Mosby Year Book, 1996; 31-47.
2. Matteson SR, Whaley C, Secrist VC. Dental Radiology Practice and Equipment. In Dental radiology, 4th ed. Chapel Hill, University of North Carolina Press, 1988; 14-16.
3. Miles DA, Van, Dis ML, Jenson CS, Ferretti A. Radiographic Imaging for Dental Auxillaries, 2nd ed, Philadelphia, WB Saunders, 1993; 50-54,66,74,80,156.
4. Meredith WJ, Massey JB. Fundamental Physics of Radiology, Second edition, Bristol: John Wright and Sons. 1972.
5. Times of India, Mumbai, Friday, March 11, 2005; 15.

10

Processing

Processing is a collective title given to a series of operations carried out in the dark room, which effect chemical changes in the exposed radiographic film, making the invisible latent image, contained in the sensitized film emulsion into a visible, permanent radiographic image.

Latent image: A radiographic film is a recording medium used in dental radiography. When this film is exposed to the information carrying beam of photons exiting an object, the photosensitive silver halide crystals in the film emulsion interact with these photons and are chemically changed. These chemically altered crystals are said to constitute the latent (invisible) image of the film.

These chemical changes in the crystals increase the liability of crystals to chemical action of the developing process that converts the latent image into manifest (visible) image.

FORMATION OF THE LATENT IMAGE (FIG. 10.1)

The film emulsion is made up of silver bromide crystals and silver iodide crystals that have been precipitated in gelatin and layered on a thin sheet of transparent base.

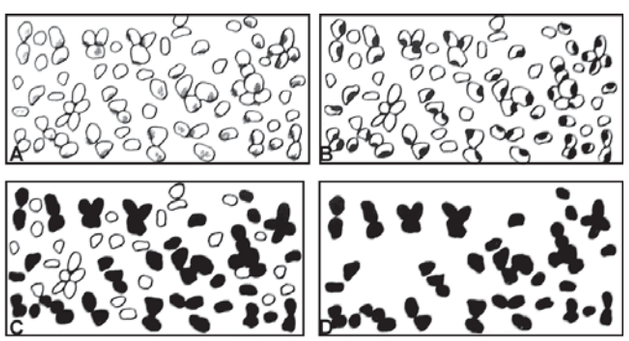


Fig. 10.1A to D: A. Schematic distribution of silver halide grains. The gray areas indicate a latent image produced by exposure. **B.** Partial development begins to produce metallic silver (black) in exposed grains. **C.** Development completed. **D.** Unexposed silver grains have been removed by fixation

The silver halide crystals are imperfect in various aspects:

1. Interstitial silver ions: These are free ions in the spaces between the crystalline lattice.
2. Physical distortion are present in the regular rectangular array of silver and bromide ion crystals due to the presence of iodine atom occupying some of the bromide sites.
3. The silver halide crystals are chemically sensitized by the presence of sulphur compounds which cause physical irregularities in the crystal produced by iodide ions, and these are called latent image sites.

The function of these latent image sites is to begin the process of image formation by trapping the electrons generated when the emulsion is irradiated.

When the silver halide crystals are irradiated by X-ray photons it will result in the release of electrons usually by the bromide ions, (by compton and photoelectric interactions) which are converted to bromine atoms, by the removal of an electron (recoil electron). This recoil electron thus produced has sufficient kinetic energy with which it moves in the crystal and strikes the image site, imparting a negative charge to that region.

The free, positively charged interstitial silver ions are attracted to the negative latent image site and neutralize the image site with the result that an atom of metallic silver is deposited at the site.

After exposure of a film to radiation, the aggregate of silver atoms at the latent image sites, comprises the latent image. It is the metallic silver at each latent image site that catalyses the development of the halide crystal in which it formed and renders the crystal sensitive to development and image formation.

The primary action of the processing solutions is to convert the crystals with latent images into black metallic silver grains that can be visualized and to remove the unexposed silver bromide crystals.

Film Processing

This process makes the latent image produced in the film emulsion by exposure to radiation, visible.

Under special darkroom conditions, a chemical reaction takes place when a film with the latent image is immersed in a series of special chemical solutions. During processing a chemical reaction occurs, and the halide portion of the exposed, energized silver halide crystal is removed chemically, this is referred to as reduction. Reduction of the silver halide crystals results in precipitated metallic silver.

During film processing selective reduction of the exposed silver halide crystal occurs. Selective reduction refers to the reduction of the energized, exposed silver halide crystals into black metallic silver, while the unenergized, unexposed silver halide crystals are removed from the film.

Thus the latent image is made visible through the following processing procedure.

- The film is placed in a chemical known as the developer solution for a specific amount of time and at a specific temperature. The developer distinguishes between the exposed and unexposed silver halide crystals. The developer initiates a chemical reaction that reduces the exposed silver halide crystals into metallic silver and creates dark or black areas on a dental radiograph. At the same time the unexposed silver halide remains virtually unaffected by the developer.
- If the developer is allowed to remain in prolong contact with the silver bromide crystals that do not contain a latent image, it will slowly reduce them also and there by over develop the film. Reduction of unexposed crystals results in the production of a chemical fog and not a dark radiograph.
- Following the developing process, the film is rinsed in water to remove any remaining developer solution. After development the film emulsion swells and becomes saturated with developer. At this point the films should be rinsed for 30 seconds with continuous, gentle agitation. Rinsing dilutes the developer, slowing down the developing process. It also removes the alkali activator, preventing neutralization of the acid fixer. The rinsing process is typical for the manual method but is not used in the automatic processing.
- Next the film is placed in a special chemical known as the fixer solution, for a specific amount of time. The fixer solution removes the unexposed silver halide crystals and creates white or clear areas on the dental radiograph. The undeveloped silver bromide gives the film a dense opalescent appearance and if exposed to light in this state the film will darken slowly.

  The black metallic silver is not removed and remains on the film.

  A second function of the fixer solution is to harden and shrink the film emulsion.
- Following the fixing process the film is washed in water to remove any remaining traces of the chemical solutions. Washing efficiency declines rapidly when the water temperature falls below 60° F. Warm water should not be used as the emulsion will soften and the film will be easily damaged. Any silver compound or thiosulfate that remains because of improper rinsing discolors and causes stains, which are most apparent on the radiopaque (light) areas. This discoloration results from the thiosulfate reacting with the silver to form brown silver sulphide, which can obscure diagnostic information. (seen as yellow stains or white deposits). Washing time longer then 30 minutes should be avoided as this may also damage the film emulsion.
- Drying: After throughly rinsing the film is dried. The films may be placed in a drying cabinet or hung up in a well ventilated dust free room. Care should be taken that the wet emulsion is not touched or damaged. Films should not be splashed with water during the drying cycle as this will produce spots which cannot be removed and reduce the diagnostic value of the film.

  After the films have been removed the hangers should be cleaned in running water to remove any traces of residual chemicals. Periodically hangers should be soaked overnight in acetic acid and scrubbed in warm soapy water. The hanger should be throughly clean and dry before a new film is loaded on it.
- Mounting of the radiograph: This helps to preserve and maintain the radiograph as these are important components of a patient's record. A mounted radiograph is more convenient for visualization. Each film mount should be correctly inscribed with the patient's name, and the relevant date for identification and indexing, for record purpose. The convex side of the dot in the corner of the intra oral film should be placed towards the viewer.

The visible image that results on the radiograph is made up of black, white and gray areas.

Radiolucent structures are those that readily permit the passage of the X-ray beam and allow more X-rays to reach the film, more silver halide crystals in the film emulsion are exposed and energized, thus resulting in increased deposits of black metallic silver. A radiograph with large deposits of metallic silver appears black or radiolucent.

Radiopaque structures are those that resist the passage of the X-ray beam and restrict or limit the amount of X-rays that reach the film. If no X-rays reach the film, no silver halide crystals in the film emulsion are exposed, and no deposits of metalic silver are seen. A radiograph with

areas of unexposed silver halide crystals that have been removed during processing and no metallic silver deposits appears white or radiopaque.

Film Processing Solutions

These may be obtained in the following forms:
- Powder.
- Ready to use liquid.
- Liquid concentrate.

The special chemical solutions are:
a. Developer solution.
b. Fixing solution.

a. Developer Solution
   i. *Reducing agents*
      - *Hydroquinone (paradihydroxy benzene)*: It is a benzene derivative and is concerned with the production of high contrast in the radiograph. Hydroquinone becomes relatively inactive in low temperatures.
      - *Metol or elon (mono methyl-para amine phenol sulphate):* It is a by product of analine dyes and helps develop the shadow areas or shades of gray on the film and brings out the details. It does not produce a high contrast. It is less sensitive to temperature changes.

        When used together hydroquinone and metol produce an adequate contrast and detail, at 68° F or 20° C.
      - *Metol phenidone (1-phenyl-3-pyrazolidone)*: This serves as the first electron donor that converts silver ions to metallic silver at the latent image site. The electron transfer generates the oxidized form of phenidone. Hydroquinone provides an electron to reduce the oxidized phenidone back to its original active state so that it can continue to reduce silver halide grains to metallic silver.

        This is an efficient activator for hydroquinone at a very low concentration and works at a lower alkalinity. It has longer keeping properties and is less likely to cause dermatitis. A special restrainer should be used to prevent excessive fogging.

        This agent is used in automatic processing.

   ii. *Preservative*
      - *Sodium sulphite*: This inhibits the tendency of the developing agent to combine with the oxygen dissolved in water or in the air. It therefore acts as a preservative and keeps the solution in an usable condition for several weeks.

        Oxidation of the developing agents forms colored substances which would stain the film and add to the film fog.

   iii. *Activator*
      - *Potassium carbonate or sodium carbonate*: It is added to the developing solution to provide and maintain the degree of alkalinity in which the developing agent can function. This is also called the 'accelerator' because it speeds up the development. A low degree of alkalinity will slow down the process of development.

        Excessive alkalinity will cause rapid reduction even of unexposed silver bromide crystals and produce fog.

        It may also soften the gelatin which may swell and may even blister or frill.

        This component of the developing solution makes it 'soapy' to touch.

        Sodium hydroxide in conjunction with sodium carbonate may be used to give higher contrast.

   iv. *Restrainer*
      - *Potassium bromide or benzotriazole*: It has a restraining action, in that it slows down the reduction action of the developing agents, and has it's greatest retarding effect on the development of unexposed crystals.

        It prevents excessive fogging of the film and increases the contrast.

   v. *Hardener*
      - *Glutaraldehyde*: This is added especially in automatic processing, to prevent the emulsion from softening and sticking to the rollers.

   vi. *Fungicide*: To prevent bacterial growth.

   vii. *Buffer*: To maintain the pH (+ 7)

   viii. *Solvent*
      - Water: It is used as a solvent of the chemicals and as a medium in which they react with the silver bromide of the film emulsion.

        Normal water supply is usually satisfactory but water with a high calcium content may cause some precipitation. Water carries metallic impurities or hydrogen sulphide which may cause trouble, to avoid these inconveniences distilled water should be used.

In automatic processing sulphate compounds are added to the developer to minimize the swelling of the emulsion so that the films can be transported by the rollers uniformly.

The developer should always be made up in accordance with the instruction of the manufacturer. The tank must be covered by a lid and the solution kept at 68° F or at the temperature recommended by the manufacturer.

If the developer is cold, its action will be slow and the time required for the full development is unduly long.

When the developer is too warm, the image develops quickly, the development time is short and it gives rise to uneven development and excessive fog.

At very high temperatures the emulsion may be excessively softened.

Developer replenisher: In the normal course of processing, phenidone and hydroquinone are consumed, and bromide ions and other by products are released into the solution. Developer also becomes inactivated by exposure to oxygen. These actions produce a 'seasoned' solution, and the film speed and contrast stabilize. The developing solution of both manual and automatic developers should be replenished with fresh solution each morning to prolong the life of the seasoned developer. The recommended amount to be added daily is 8 ounces of fresh developer (replenisher) per gallon of developing solution, if approximately thirty periapical films or five panoramic films are developed per day. Some of the used solution may need to be removed to make room for the replinisher.

b. Fixing Solution,

i. *Clearing agent*

- *Ammonium thiosulphate or sodium thiosulphate (hypo)* is one of the few substances which will remove silver bromide without adverse effect on the film. The chemical reacts with the undeveloped silver bromide and converts it into a soluble substance which can be subsequently washed out of the film.

ii. *Preservative*

- *Sodium sulphite*: It prevents the oxidation of the clearing agent, which is unstable in the acidic environment. It also binds with any colored oxidized developer carried over into the fixing solution, and thus prevents any oxidized developer from staining the film.

iii. *Acidifier*

- *Acetic acid*: The acetic acid buffer system (pH 4 to 4.5) helps to keep the fixer pH constant. This acidic pH is required to promote good diffusion of the thiosulphate into the emulsion and of silver thiosulphate complex out of the emulsion.

The acid solution also neutralizes any developing agent carried over, thereby blocking any further development of any unexposed crystals while the film is in the fixing tank.

iv. *Hardener*

- *Aluminum chloride or aluminum sulphate or potassium alum*: These substances form complexes with the gelatin during fixing and prevent further damage to the gelatin during subsequent handling. The hardeners also reduce the swelling of the emulsion during the final wash. This lessons mechanical damage to the emulsion and limits water absorption, thus shortening the drying time.

v. *Solvent*.

- *Water*.

The fixing solution should be made up in accordance with the manufacturer's instructions and used at a temperature of about 68°F (20°C). In order to clear completely films must remain in the fixer for at least twice the time they were kept in the developing tank. The clearing time will depend upon the type of film and the activity of the fixing solution. With usage the fixer becomes progressively slow in its action and when the clearing time for a given type of film has doubled, the fixer is considered exhausted. It should be replaced by a fresh solution.

It is not advisable to switch on the light until the film has been in the fixer for about 30 seconds, this will ensure that the development process has stopped.

No film should be exhibited for general viewing until it has been throughly fixed.

Reduction : An overexposed or grossly overdeveloped film will be too dark for convenient viewing, owing to the excessive deposit of silver which obscures the image detail.

A photographic reducer contains an oxidizing agent, potassium ferricyanide which oxidizes the silver to silver ferrocyanide, which in turn is dissolved by the solution of sodium thiosulphate. This is known as the Farmer's Reducer and consists of two solutions:

Solution A : Potassium ferricyanide 75 grams.
Water to make 1000 ml.

Solution B : Sodium thiosulphate crystals 240 grams.
Water to make 1000 ml.

Method: Take one part of Solution A and four parts of Solution B, and add twenty seven parts of water.

Immerse the radiograph in the mixed solution and watch carefully.

When the film has been sufficiently reduced, it should be washed in running water for 30 minutes.

The process of reduction should be carried out in a weak artificial light, as bright light causes rapid deterioration of the solution.

The Solution A and Solution B should be mixed just prior to their use.

Chemical intensification of radiographs: A radiograph may be too light because of, underexposure, under development or both. Instead of repeating the radiograph, chemical intensification may be done. Most of the intensification methods act by converting the silver which forms the image into a compound which is more opaque, more colored or of a different physical form.

A number of commercially available intensifying solutions are present:

- In-4 Chromium intensifier.
- In-5 Silver intensifier
- Copper iodide intensifying solution.
- XR-10 intensifying solution.
- Line Toner solution- this is made of three solutions:

Solution A :	Diglycolic acid	60 grams
	Sodium Hydroxide	36 grams
	Water	750 ml.
Solution B:	Boric nitrate	14 grams
	Potassium fluoride	1 gram
	Water	100 ml.
Solution C:	Potassium ferricyanide	5 grams
	Sodium nitrite	1 grams
	Water	100 ml.

The processed radiograph which is of low density is immersed in the intensifying solution for a period of three to eight minutes depending upon the density increase required.

The Dark Room

The primary function of the dark room is to provide a completely darkened environment where the X-ray film can be handled and processed to produce a diagnostic image in an efficient, precise and standardized procedure.

Since the processing operations are carried out in near total darkness, every piece of equipment must be in a specific place.

General Lay Out (Fig. 10.2)

The size of the dark room for a dental office may be as small as 3 feet × 3 feet for an individual dentist, or may measure 16 to 20 square feet for a group practice or in an institution.

The size will vary depending upon:

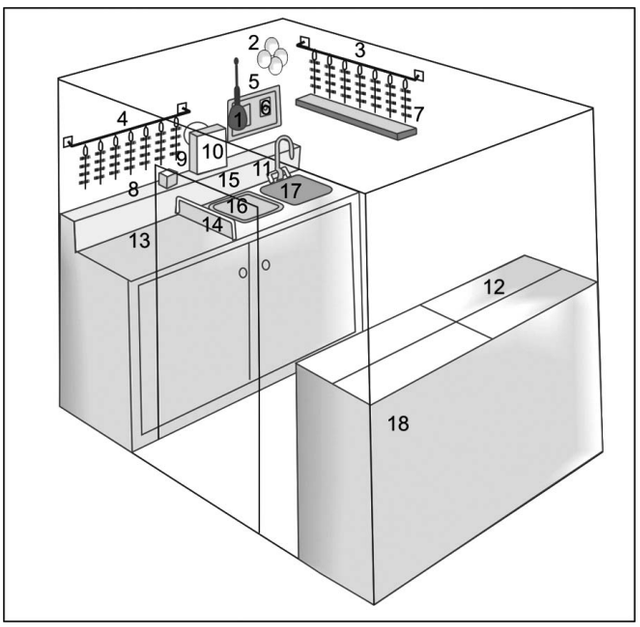


Fig. 10.2: Schematic Dark Room Layout

1. Darkroom lamp, **2.** Electric fan, **3.** Rack for drying films, **4.** Storage rack for intraoral hangers, **5.** Bulletin board, **6.** Exposure and processing chart for dental X-ray films, **7.** Drip pan, **8.** Shelf, **9.** Timer, **10.** Utility safe lamp, **11.** Goose neck faucet, **12.** Loading area, **13.** Processing area, **14.** Splash board, **15.** Hot and cold water valves, **16.** 8 × 10 dental processing tank, **17.** Utility sink, 1**8.** Supply cabinet for chemicals, cassettes and other accessories

- Volume of radiographs processed.
- Number of persons using the dark room.
- Type of processing equipment used. (processing tanks or automatic processor)
- The space required for the duplication of films and storage.

The dark room should have sufficient space to accommodate the processing tanks or automatic processors.

The dark room work space must include an adequate counter area where films can be unwrapped prior to processing. This area should be absolutely clean, dry and free of processing chemicals, water, dust and debris. This should ideally be at least three feet away from the processing tank.

The darkroom storage space must include ample room for chemical processing solutions, film cassettes and other miscellaneous radiographic supplies.

In busy hospitals, it is convenient to have built in hatches in the walls of the dark room through which cassettes may be passed to and from the operating radiographic rooms to the darkroom.

The dark room should be well ventilated, the use of an air conditioner is recommended, but during non working hours the windows and doors should be left open.

Fumes emitted from the chemical processing solutions may damage film emulsion of unexposed films, leading to film fog.

The temperature and humidity level of the darkroom must be controlled to prevent film damage. A room temperature of 70°F and humidity levels between 50 to 70% is recommended to be maintained.

The dark room plumbing must include both hot and cold running water along with mixing valves to adjust the water temperature in the processing tanks.

A utility sink with running water is also useful in the darkroom.

Other miscellaneous darkroom requirements include a waste basket for disposal of all film wrappings and an X-ray view box that is used to view radiographs.

Illumination

As the term darkroom suggests the room must be completely dark and must exclude all visible light – Light Tight. or Light Proof which may be accomplished:

By exclusion of all external lights.

By use of a light tight door or the door should have a lock to prevent accidental exposure of the film.

Fluorescent lights should not be used in the dark room because there is often a short after glow that may fog the first few films opened after the light is turned off.

Use of both white light and safe light.

White light illumination is required during cleaning tanks and preparing the solutions.

Safe Light illumination (Fig. 10.3)

a. Should be of low intensity, with a relatively long wave length (orange-red) that does not rapidly affect open film, but permits one to see enough of the work area.
b. Films are sensitive to light until after fixation.
c. Arrangement of safe light filter should be such that threes zones of illumination are provided:
   i. *Dimmest zone*: Area where the cassettes are loaded and intra oral films opened.
   ii. *Medium zone*: Area where the films are developed and fixed.
   iii. *Bright zone*: Area where the films are washed and placed in the drier.

   This can be accomplished by placing one safe light above the working area and another on the wall behind the processing tanks.

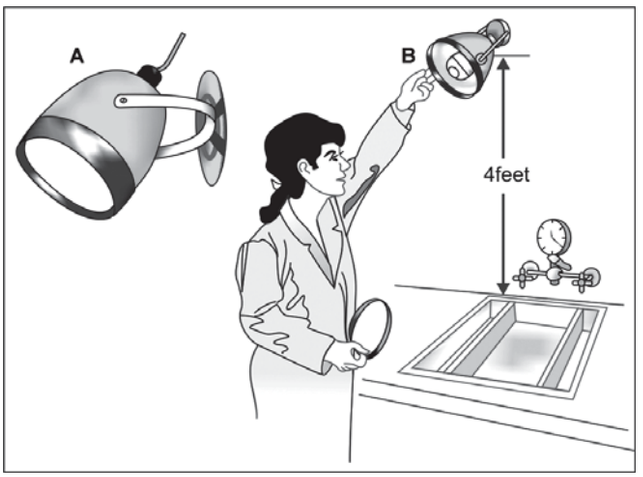


Fig. 10.3: A. The safe light uses a GBX-2 filter and 15 watt bulb; **B.** A safe light may be mounted on the wall or ceiling in the darkroom and should be at least 4 feet from the work surface

Excessive exposure of film to safe light illumination will result in fog. The following three factors must be therefore considered:

i. *Type of filter*:
   X-rays have the highest sensitivity in the blue green region of the spectrum and are less sensitive to light in the yellow and red region.

   Hence safelights are safe when made of amber or red filters. The filters commonly used are:
   - Moralite Filter (cannot be used for screen films)
   - Wratten Series 6 B filters.
   - Red GBX-2 safe light filter.

ii. *Intensity of illumination*:
   To minimize fogging effect of prolonged exposure;
   The wattage of the bulb should be 7½ to 15 watts.
   The distance of the safe light above the work area should be 4 feet.

   The light illumination follows the inverse square law, which states that the intensity is inversely proportional to the square of the distance. Thus correct intensity can be obtained by adjusting either the distance of the bulb or wattage or both.

iii. *Time of exposure*:
   More the film is exposed to the safe light, more are the chances of film fogging. Film handling under a safelight should be limited to about 5 minutes before the film emulsion shows some sensitivity to light from a safe light with prolonged exposure.

Tests for Checking Unsafe Illumination

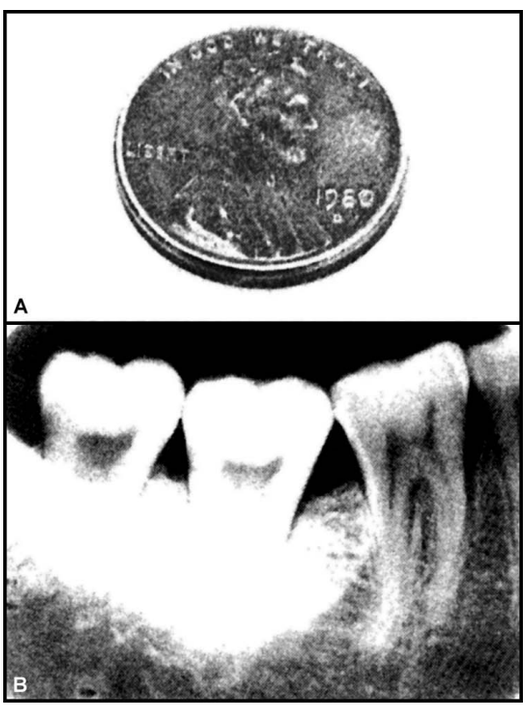
Film fogging can occur due to:

i. Use of inappropriate safe light filters.

ii. Excessive exposure to safe light filters.
iii. Stray light.

a. Coin test/penny test (Figs 10.4A and B) is a test to evaluate for fogging caused by inappropriate safe lighting conditions.
   – Shut all lights and put on the safe lights.
   – Open film packet and place the base film in the area where films are usually unwrapped.
   – Place a coin on the film and leave it in this position for approximately the time required to unwrap and mount a full mouth set of radiographs, usually 5 minutes.
   – Develop the test film as usual.
   – Inference: If the image of the coin can be seen on the resultant film, the room is not light safe for the particular film tested.

b. To check whether there is no light leak, shut the door and shut off all the lights in the dark room. A few minutes after you become accustomed to the darkness, carefully view all the areas, like periphery of doors and windows to check whether any light from outside is been seen inside the dark room.



Figs 10.4A and B: Penny test for unsafe illumination, **A.** Leave a penny on the exposed duplicate film from the double film pack on the working surface during the time that any film would be opened usually about five minutes. **B.** If the processed radiograph shows an out line of the penny, the film is being fogged by inappropriate safelight conditions

Processing Equipment

Dental X-ray film is processed in the darkroom using manual processing techniques or an automatic film processor.

Special equipment is required for both.

Manual processing (also known as Hand or Tank processing).

This is the simplest and most efficient procedure for developing with accurate control.

The processing tank contains two parts: (Fig. 10.5)

i. Master tank : Size 8″ × 10″
   This serves as a heater jacket to hold the insert tanks and is large enough to provide space between the two insert tanks for rinsing and washing of the films when necessary. It also helps to maintain the temperature of the developer and the fixer in the insert tanks. An over flow pipe is used to control the water level in the master tank.
   Master tank should have a cover:
   - To reduce oxidation of the processing solution.
   - To protect the developing film from accidental exposure to light.
   - To minimize evaporation of processing solution.
   - To prevent contamination with dust.
   - There should be running cold and hot water facility. The ideal temperature is recommended to be 70°F.

ii. *Insert tanks*: Are removable containers for individual processing solutions. Developer is placed in the insert tank on the left side of the master tank and the fixer on the right side.
   Insert tank should have a capacity of to hold one gallon of developer or fixer.

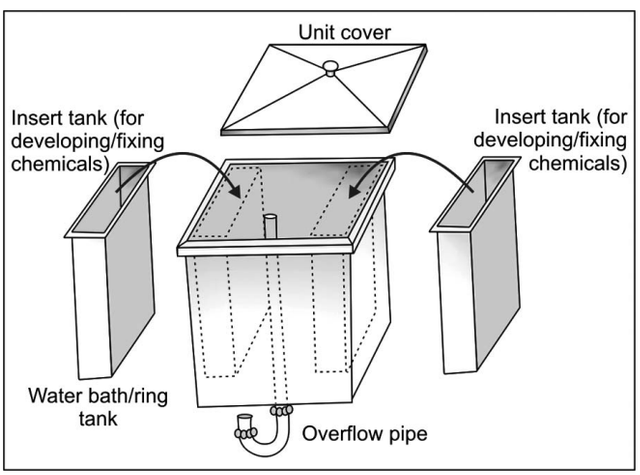


Fig. 10.5: Processing tank, the developing and fixing tanks are inserted into the bath of running water with an over flow drain

All three tanks must be made of stainless steel (ISI Type 316 s.s. with 2.3% Molybdenum)

1. Stainless steel is preferred as:
   - It does not react with the processing solution.
   - It accomodates more rapidly to change in temperature of the water in the master tank.
   - It is easy to clean.
2. Enamel.
3. Earthenware.
4. Hard rubber.

Do not use tank or containers that have been soldered as reaction of the solution with the solder metals can cause chemical fogging.

Thermometer (Fig. 10.6): A thermometer is required to check and maintain the temperature of the developing, fixing and washing solutions.

It may be clipped on to the side of the tank or left free floating in the tank.

Timer: is required to control the time of development and fixation.

Drying racks: Wet films are subjected to damage from scratching and abrasion if not handled properly.

Films should be dried in a dust free environment, by:

- Merely hanging a rack above a drip tray to catch the run-of excess water.

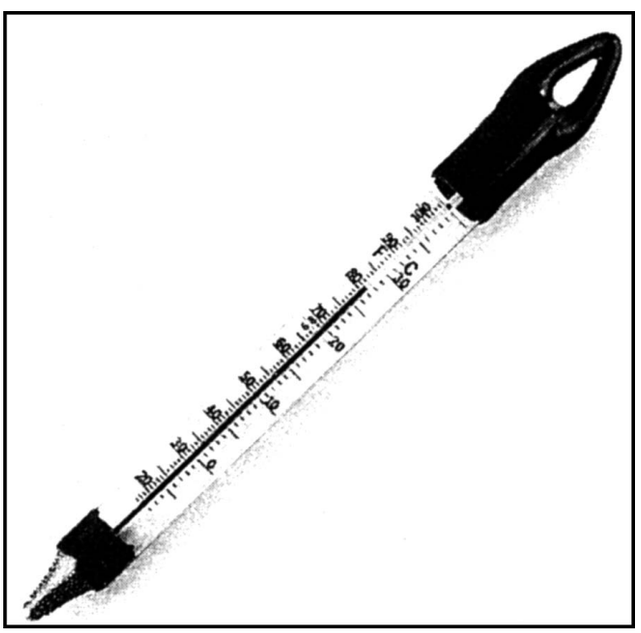


Fig. 10.6: An example of a floating thermometer

- Electric fan can be used to speed the drying of films.
- Cabinet dryer using moderately dry air.

Stirring rod or stirring paddle: This is necessary for manual processing. A stirring rod is used to agitate the developer and fixer solution prior to developing, so as to mix the chemicals and equalize the temperature of the solutions. It may be made of plastic or glass.

Plastic apron: Used to protect clothing during the processing of films and mixing chemicals.

Different Methods of Processing

1. Manual method
   i. Time temperature method
   ii. Visual method
   iii. Rapid processing method
2. Automatic method
3. Monobath method
4. Day light method
5. Digitized processing method
6. Self developing films.

Manual Method

i. ***Time temperature method***: This method is best for mass processing of radiographs, keeping all other exposure parameters standard (kVp, mAs, exposure time, etc). The films do not have to be viewed during the developing process and a large number of films can be processed at one time.

This method ensures that the developing is standard thus any change in the image quality in regards to density or contrast reflects of disparity in the exposure parameters.

- Replenish solutions – the first step is to replenish the developer and fixer. Check the level of the solutions to ensure that the film on the top clips of the hanger will also be adequately immersed.
- Stir the solutions, with a separate paddle for the developer and fixer. Check the temperature of the developing solution, the optimum temperature is 68° F to 70° F. If the temperature of the solution is outside this range, the circulating water temperature must be adjusted accordingly, to reach the correct temperature. (Table 10.1)
- Mount the film on hangers- (Fig. 10.7) label the hangers with the name of the patient and date. Close and lock the door of the dark room, turn

Table 10.1: Processing temperature and times

Solution temperature	*Time in developer (minutes)*	*Rinse time (minutes)*	*Time in fixer (minutes)*	*Wash time (minutes)*
65°F. (18.5°C)	6.0	0.5	10-12	20
68°F (20.0°C)	5.0	0.5	10	20
70°F (21.0°C)	4.5	0.5	9-10	20
72°F (22.0°C)	4.0	0.5	8-9	20
75°F (24.0°C)	3.0	0.5	6-7	20
80°F (26.5°C)	2.5	0.5	5-6	20

off the over head white light and switch on the safe light.

For intra oral films, carefully unwrap each exposed film over a clean working surface using proper infection control procedures. Dispose of all film packet wrappings.

For extra oral film, remove the film from the cassette.

Handle all films by the edges only.

Clip each film to the labeled film hanger. Verify that each film is securely attached by running a finger along the film edge. Reattach any loose films.

- Based on the temperature of the developing solution and the instructions of the manufacturer, set the timer. For intra oral film processing in conventional solutions, the following development times are recommended: (Table 10.1)

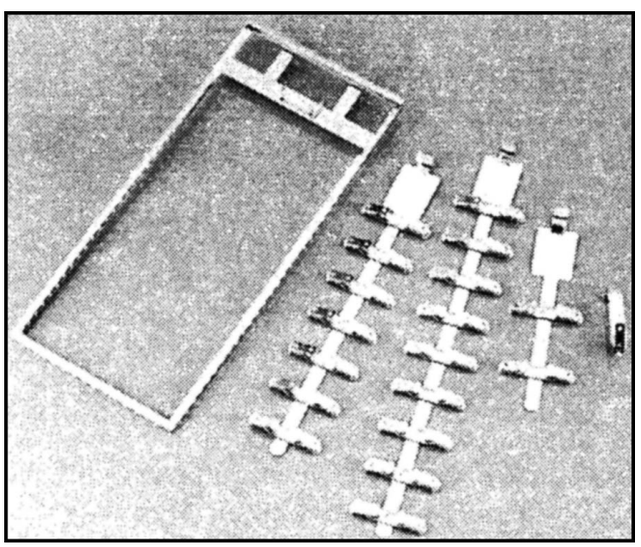


Fig. 10.7: A variety of film hangers

Processing at either higher or lower temperatures and for longer or shorter times than that recommended by the manufacturer reduces the contrast of the processed film. Processing for too long or at temperatures higher than those recommended can result in film fog, which will diminish film contrast and diagnostic information.

- Develop the films by first starting the timer mechanism and gently immerse the film hanger into the developing solution. Make sure that the films do not contact another film or the side of the processing tank. Gently agitate the hanger up and down to prevent air bubbles from clinging to the film. Hang the hanger on the film rack on the edge and leave it for the predetermined time without further agitation. Cover the processing tank.

  Before immersing the film in the developing solution it is advisable to wet the film uniformly in water, so that the action of the developing solution is uniform.
- When the timer goes off, uncover the processing tank, remove the film hanger, drain the excess developer in the wash bath. Place the hanger in the circulating water of the master tank. Agitate for 20 to 30 seconds. Remove and drain the excess water for several seconds. This will remove the excess developer, thus slowing the development and reducing the contamination of the fixer solution.
- *Fixation*: Based on the development time, the fixation time is determined and the timer is set. A time temperature chart is used to determine the time intervals. Fixation is usually approximately double the development time.

  Place the film hanger in the fixer solution for the given time. Agitate for 5 of every 30 seconds. This eliminates bubbles and brings fresh fixer into contact with the emulsion. Hang the hanger on the film rack on the edge of the insert tank, and cover the processing tank.

  When the timer goes off, uncover the processing tank, remove the hanger and allow the excess fixer to drain into the fixer tank. Place in circulating water.

  Excess fixation removes some of the metallic silver grains, diminishing the density of the film.

- After fixation of the films is complete, the hanger is placed in running water for at least 10 minutes to remove residual processing solutions. After the film has been washed, remove surface moisture by gently shaking excess water from the film and hanger. Cover the processing tank.
- Dry the film. To air dry the films, suspend the film hanger with the films from a rod or drying rack in a dust free area over a drip pan. If a heated drying cabinet is used, the temperature should not exceed 120°F. If the films dry rapidly with small drops of water clinging to their surface, the areas under the drops dry more slowly than the surrounding areas. This uneven drying causes distortion of the gelatin, leaving a drying artifact. The result is spots that frequently are visible and detract from the usefulness of the finished radiograph.

  After drying the films are ready to mount.
- Remove the dry radiograph from the film hanger and place them in an envelope labeled with the patient's name and date of exposure. Out side the dark room, use a view box to examine the radiograph and place them in a labeled film mount.

After the manual procedures have been completed, clean all processing equipment that was used and clean all work surfaces. A clean dark room is essential for the production of diagnostic radiographs.

The interaction between the mineral salts in water and the carbonate in the processing solutions deposits on the inside of the insert tanks. Such deposits contaminate the processing solutions. The master and insert tanks must be cleaned each time the solutions are changed. A commercial stainless steel tank cleaner or a solution of hydrochloric acid and water (1.5 ounces HCl to 128 ounces of water) can be used to remove the mineral salts and carbonate deposits. Abrasive type cleaners are not recommended as they may react adversely with the processing solutions.

Changing solutions: All processing solutions deteriorate as a result of continuous processing and exposure to air. Replenishing prolong their life but the build up of the reaction products eventually causes the solutions to cease functioning properly.

Exhaustion of the developer results from oxidation of the developing agents, depletion of hydroquinone and build up of bromide. Use of an exhausted developer results in films that show reduced density and contrast.

When the fixer becomes exhausted, silver thiosulphate complexes and halide ions build up. The increased concentration of the silver thiosulphate complexes slows the rate of diffusion of these complexes from the emulsion. The halide ions slow the rate of clearing of unexposed silver halide crystals. These changes result in films with incomplete clearing that turn brown with age.

A simple procedure can help determine when solutions should be changed. A double film packet instead of a single film packet is exposed on one projection for the first patient radiographed after new solutions have been prepared. One of the film is placed in the patients chart and the other is mounted on a corner of a view box in the dark room. As successive films are processed, they are compared with this reference film. Loss of image contrast and density become evident as the solutions deteriorate, indicating when the time has come to change them. The fixer is changed when the developer is changed.

ii. ***Visual method***: This manual method consists of placing the films in the developing solution and viewing them from time to time in the safe light, thus the degree of developing is at the operator's discretion.

The advantage of this method is that the film can be developed to the contrast and detail desired for the particular subject. And in case the film is over exposed it is possible to get good detail by under developing.

The disadvantage is that each film has to be processed individually and is very time consuming.

iii. ***Rapid processing chemicals***: In recent years manufacturers have produced rapid processing solutions that typically develop a film in 15 seconds at room temperature. They contain a higher concentration of hydroquinone and a more alkaline pH, which causes the emulsion to swell more, thus providing greater access to the developer. This has its applications in endodontics and emergency situations. The resultant images do not have the same degree of contrast and may discolor over a period of time if not fully washed. If these are kept in the conventional fixing solution (after viewing) for 4 minutes and washed for 10 minutes, the contrast is improved and the film becomes more stable in storage.

Automatic Method (Fig. 10.8)

This method uses equipment that automates all the processing steps. There are two types:

a. Automatic Dunking Models that produces a washed film that still has to be dried.

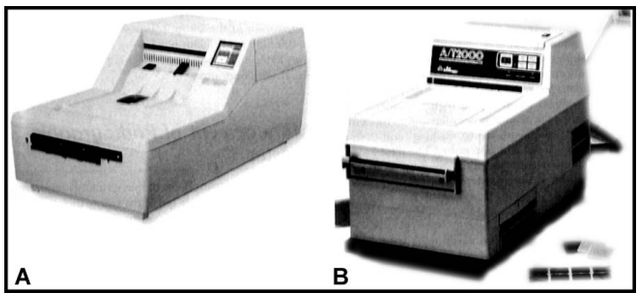


Fig. 10.8: Automatic film processors. **A.** Excel. **B.** A/T 2000XR

b. Miniature Roller type that produces a dried film.
The automatic processor may have a day light loading compartment for intra oral films thereby preluding the need to work in the dark room (Table 10.2).

Advantages

- Rapidity of the operation, the entire process may take less than 4-7 minutes.
- Uniformity of results.
- Less floor space required and have daylight loading capability.
- No wet films to be handled, no film hangers, and film dryer.
- No wet reading of films. A dry film is more useful diagnostically than a wet film.
- Density and contrast of the resultant radiograph are consistent.

Disadvantages

- Quality is not as high as that of a manually developed radiograph. More grain is evident in the final image.
- High cost of equipment and maintenance (Table 10.3).

Mechanism (Fig. 10.9)

The design is a in-line arrangement, consisting of a transport mechanism that picks up the unwrapped film and passes it through the developing, fixing, washing and drying sections. The transport system most often used is a series of rollers driven by a constant-speed motor that operates through gears, belts or chains. The rollers often consist of independent assemblies of multiple rollers in a rack, with one rack for each step. These assemblies are designed and

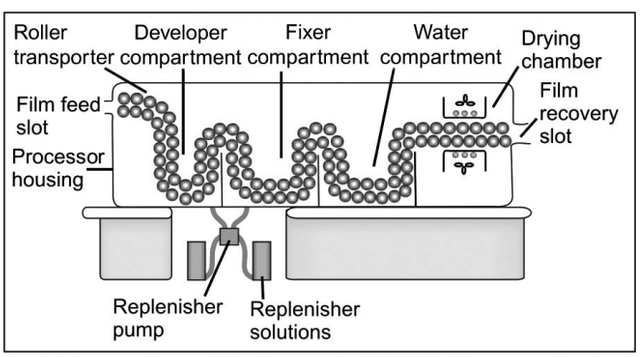


Fig. 10.9: Component parts of the automatic processor

Table 10.2: Guide to feeding of films in the automatic processor

1. Feed the film slowly and carefully, in a straight line, so as not to cause a jam-up in the processor.
2. If the film is bent, insert the unbent side of the film into the machine first.
3. Do not feed damp or wet films into the machine as it will contaminate the rollers and cause streaking.
4. Do not feed films in too quickly in succession as they may stick to each other and jam the machine.

Table 10.3: Proposed maintenance schedule for the automatic processor

A. Daily.
- Temperature of the developer should be 81° to 83°F for longer cycle.
  80°F for 5 ½ min. cycle. 83°F for 4 min. cycle.
- Drain water section daily. Run a cleaning film through each morning.
- Transport sections should be checked for proper alignment.
- Cover the processor at the end of the day but leave it slightly open to allow chemical fumes to escape.

B. Weekly.
- Soak and wash the roller sections with warm water throughly for 10 to 15 minutes, on a weekly basis. Then run at least two cleaning films through the processor before use.
- Change/replenish solutions every two or four weeks depending on the work load. Use only automatic processing solutions, manual processing solution can damage the processor.

C. Monthly.
- Clean developer section with special developer cleaner (prevents fogging of films).
- Clean fixer section with warm water (prevents formation of crystals on the rollers).
- Clean wash section with household bleach/water solution (prevents scum formation leading to spots and artifacts on films).
- Rinse all racks throughly with water after removing from cleaning solutions.
- Visually check dryer and dust as needed.
- All moving parts like, gears, sprockets, idlers, bearings, drive mechanisms and ring points should be well lubricated to prevent excessive wear of moving parts. Be careful not to allow oil to get on the rollers.

positioned so that the film crosses over from one roller to the next, the operator may also be able to remove them independently for soaking, cleaning and repairing.

The function of the roller is to:

- Primarily move the film through the developing solutions.
- Their motion keeps the solutions agitated.
- In the developer, fixer and water tanks the rollers press on the film emulsion, forcing solution out of the emulsion. The emulsions rapidly fill again with solutions thus promoting solution exchange.
- The top roller at the cross over point between the developer and fixer tanks removes developing solution, minimizing carryover of the developer into the fixer tank. Thus maintaining the uniformity of the processing chemicals.

The chemical composition of the developer and fixer is modified to operate at higher temperatures than used for manual processing and to meet the more rapid development, fixing, washing and drying requirement of automatic processing. The fixer has an additional hardener that helps the emulsion withstand the rigors of the transport system.

Replenishment

It is important to maintain the developer and fixer carefully to preserve the optimal sensitometric and physical properties of the film emulsion within the narrow limits of the speed and temperature of automatic processing. To compensate for the loss of activity some automatic processors include an automatic replenisher system. As in the manual processing, 8 ounces of fresh developer and fixer should be added per gallon of solution per day, assuming that 30 intra oral or 5 extra oral films are developed per day.

Insufficient replenishment of the developer results in a loss of contrast.

Exhaustion of the fixing solution causes poor clearing, insufficient hardening, and unreliable transport from the fixer assembly to the drying operation.

Monobath Method

In this method the developer and fixer are combined in one solution. The fixer is alkaline and does not neutralize the developer. This monobath is injected into a special water proof film packet and the film is developed by simply rubbing the film packet. There is no need of a dark room.

Advantage

- It is ideal for root canal treatment or in cases of quick spot diagnosis.

Disadvantage

- The alkaline type of fixer very rapidly oxidizes under atmospheric conditions.
- Results are not satisfactory as in conventional processing as the fixing starts while the developing process is in progress.

Day Light Method

This is carried out in a special device provided with safe light filters and two glove like compartments through which the operator can put his hands and develop the films. The films are opened and processed in subdued daylight.

There is no need of the dark room.

This requires a special day light film by Kodak to be used.

The emulsion consists of a yellow dye and the film appears yellow and black instead of the coventional blue white and black.

Digitized Processing Method

Self Developing Films (Figs 10.10A and B)

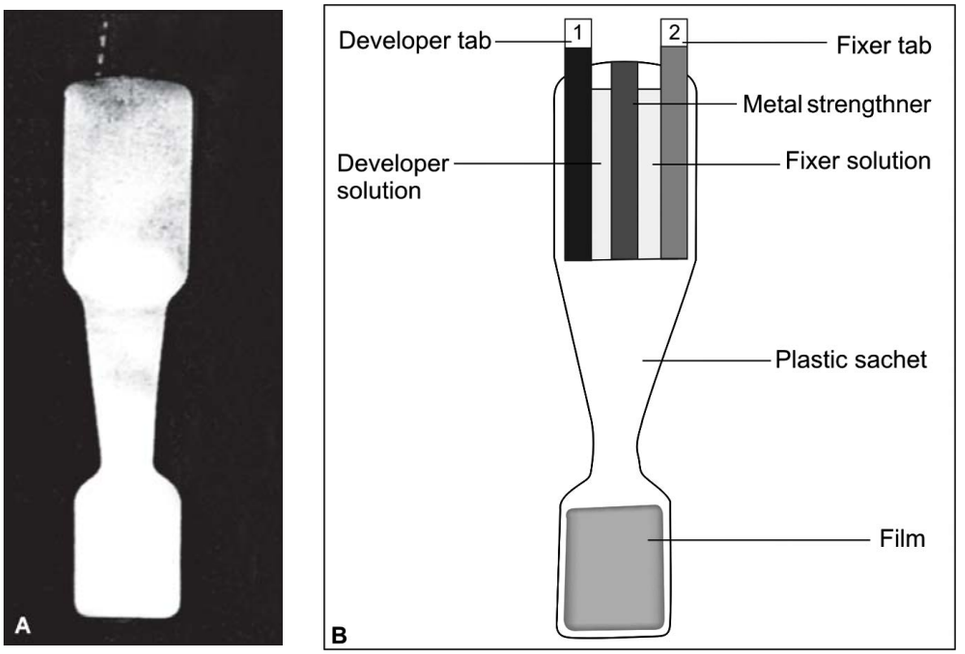
These are a recent advance in manual processing. The X-ray film is presented in a special sachet containing developer and fixer (Fig. 10.10). Following exposure the developer tab is pulled, releasing developer solution which is milked down towards the film, and massaged around it. After about 30 seconds the fixer tab is pulled to release the fixer solution which is similarly milked down to the film. After fixing, the used chemicals are discarded and the film is rinsed throughly under running water for about 10 minutes.

Advantages

- No darkroom or processing facilities required.
- Time saving- the final radiograph is ready in about a minute.

Disadvantages

- Poor overall image quality.



Figs 10.10A and B: A. A self developing film. **B.** Diagram showing the basic internal design

- The image deteriorate rapidly with time.
- There is no lead foil inside the film packet.
- The film packet is very flexible and easily bent.
- These films are difficult to use in positioning holders.
- Relatively expensive.
  (a rigid, plastic, backing support tray for the film is manufactured, which helps to reduce the problems of flexibility and lack of lead foil.

Table 10.4: Removing processing stains

1. Wet spots should be immediately washed with a strong concentrated soap solution.
2. Dried stains are best removed with a commercially available stain remover prior to washing it.
3. Home remedies include, weak bleach solution and vinegar immediately prior to washing the uniform.

BIBLIOGRAPHY

1. DuPont EI, DeNemours and Co. Inc. Dark room techniques for better radiographs processed manually or automatically.
2. Frommer HH. Film Processing - Darkroom. Radiology for Dental Auxillaries, 6th edition St. Louis, Mosby- year book, 1996;101-37.
3. Fuchs AW. Principles of Radiographic Exposure and Processing, 2nd ed. Springfield, III, Charles C. Thomas, 1979.
4. Goaz PW, White SC. Processing X-ray Film. Oral Radiology, Principles and Interpretation, 3rd ed. St. Louis, Mosby- year book, 1994;106-25.
5. Johnson ON, McNally MA, Essay CE. Dental X-ray Processing. Essentials of Dental Radiography for Dental Assistants and Hygienists, 6th ed. Norwalk, Appleton and Lange, 1999; 179-210.
6. Mason-Hing LR. Film Processing Darkroom and Duplicating. Fundamentals of Dental Radiography, 3rd ed, Philadelphia, WB Saunders, 1993; 20-35.

Section Five
Imaging Techniques

11

Intraoral Radiographic Techniques

The basic principles of shadow casting are:

1. The focal spot (source of radiation) should be as small as possible (Figs 11.1 and 11.2).
2. The focal spot-object distance should be as long as possible (Fig. 11.3).
3. The object-film distance should be as small as possible (Fig. 11.4).
4. The long axis of the object and the film planes should be parallel (Fig. 11.5).
5. The X-ray beam should strike the object and the film planes at right angles (Fig. 11.6).
6. There should be no movement of the tube, film or patient during exposure. (Given by Mason and Lincoln) (Fig. 11.7).

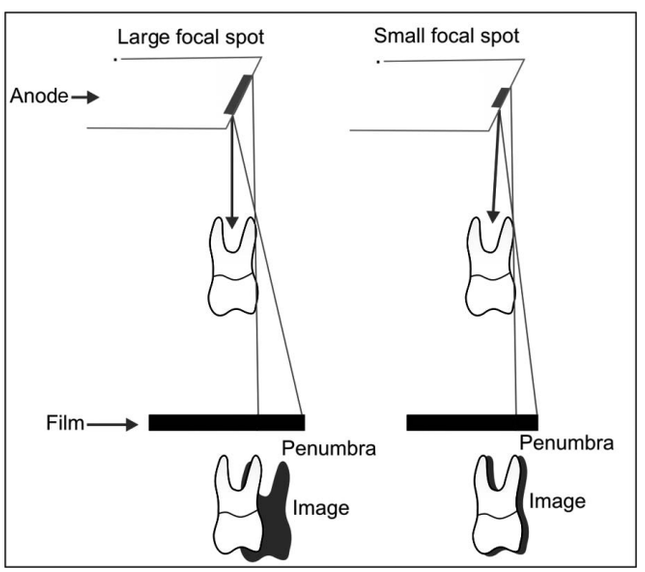


Fig. 11.1: The smaller the focal spot area, the sharper the image. Larger the focal spot area, the greater the amount of penumbra and loss of image sharpness

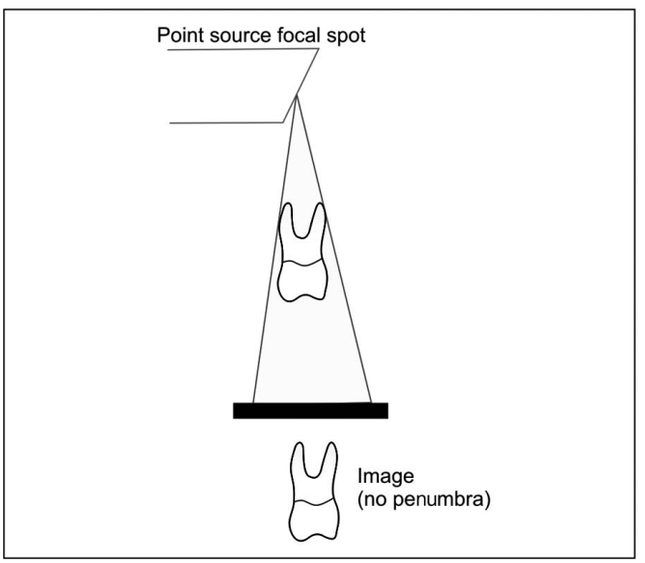


Fig. 11.2: Theoretical "point source" of X-rays would produce a sharp image without penumbra

There are three types of *Intraoral radiography*:

- *Periapical*: Showing all of the tooth and the surrounding bone.
- *Bite wing*: Showing crowns of maxillary and mandibular teeth and adjacent alveolar crests.
- *Occlusal*: Revealing an area of the tooth and bone, larger than the periapical film.

Intraoral localization techniques: Using the above techniques in combination we can help to localize objects in the oral cavity and jaws.

PERIAPICAL RADIOGRAPHY

Indications

- Detection of apical infection/inflammation.

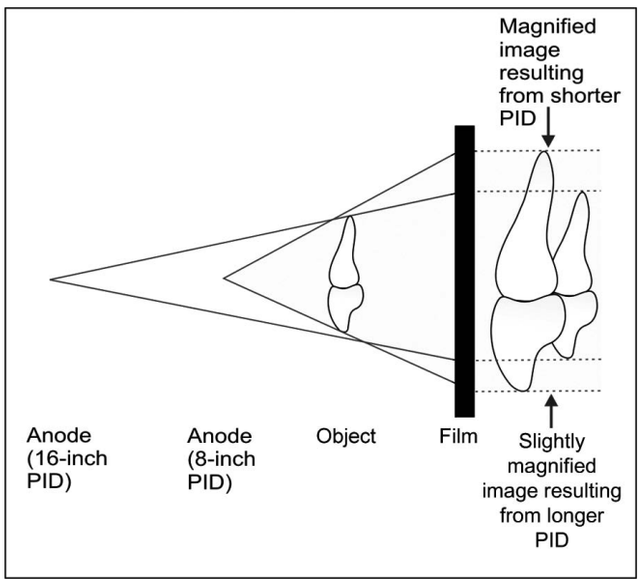


Fig. 11.3: A longer PID and target film distance results in less magnification

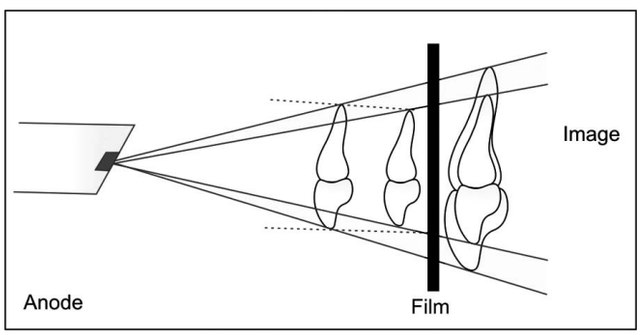


Fig. 11.4: Diagram illustrating object film distance. The closer the proximity of the tooth to the film, lesser the image enlargement

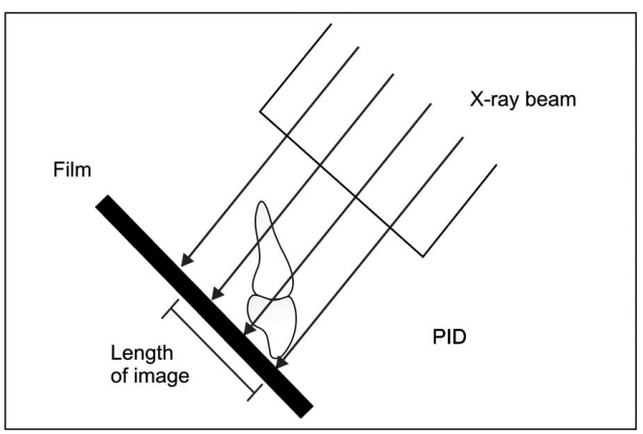


Fig. 11.5: If the tooth and the film are not parallel, an angular relationship is formed and a distorted image results. In the above diagram the length of the image that appears on the film is shorter than the actual tooth

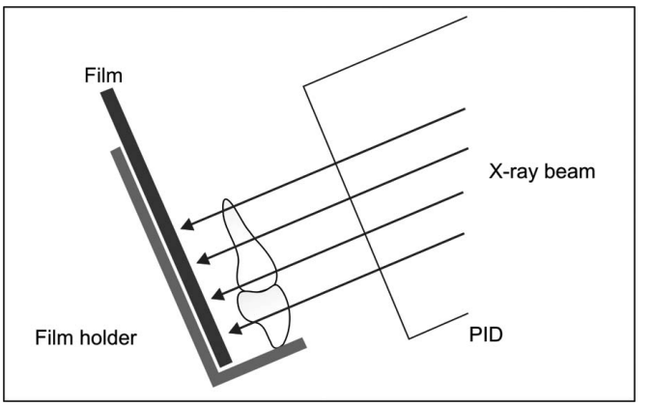


Fig. 11.6: To limit distortion, the central ray of the X-ray beam must be perpendicular to the tooth and the film

- Assessement of periodontal status.
- After trauma to assess the teeth and alveolar bone.
- Assessement of the presence and position of unerupted teeth.
- Assessement of root morphology before extractions.
- During endodontic therapy.
- Preoperative assessement and postoperative appraisal of apical surgery.
- Detailed evaluation of apical cysts and other lesions within the alveolar bone.
- Assessement of the position and prognosis of implants.

There are two techniques used to take periapical radiographs:

A. The Paralleling or Right Angle or Long Cone Technique.
B. The Bisecting Angle or Short Cone Technique.

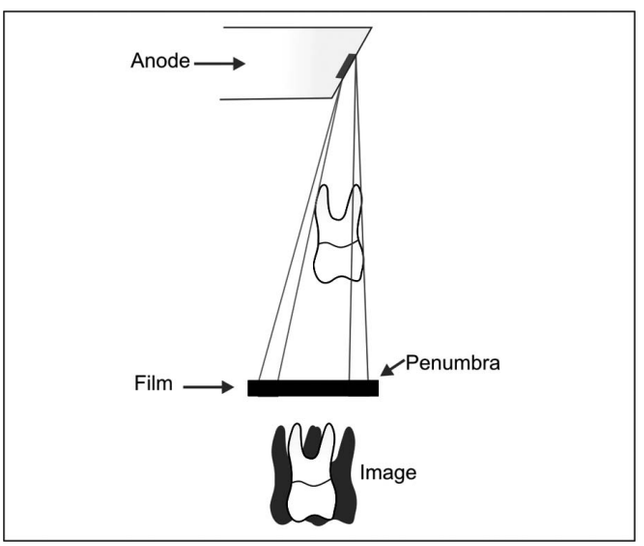


Fig. 11.7: Diagram illustrating the influence of motion on film sharpness. The image outline becomes blurred owing to penumbra formation

The Paralleling Techniques satisfies 1,2,4,5 and 6th principal of shadow casting.

The Bisecting Angle Technique satisfies 1,3 and 6th principal of shadow casting.

A. *Paralleling Technique*: (Fig. 11.8) The essence of this technique is that the X-ray film is supported parallel to the long axis of the teeth and the central ray of the X-ray beam is directed at right angles to the teeth and film. (Fig. 11.9)

To achieve parallelism between the film and the tooth, the film must be placed away from the tooth and towards the middle of the oral cavity (Fig. 11.10). Because of the anatomic configuration of the oral cavity, (e.g. curvature of the palate) the object film distance must thus be increased to keep the film parallel with the long axis of the tooth. Because the film is placed away from the tooth, image magnification and loss of definition results.

To compensate for image magnification, the target film distance must also be increased to ensure that only the most parallel rays will be directed at the tooth and the film. As a result a long (16 inch) target film distance must be used with the paralleling technique and hence this technique is also referred to as Long Cone Technique. The 'long' refers to the length of the cone or positioning device (PID).

The use of the long target film distance in the paralleling technique results in less image magnification and decreased definition.

Film holders: The paralleling technique requires the use of film holders.

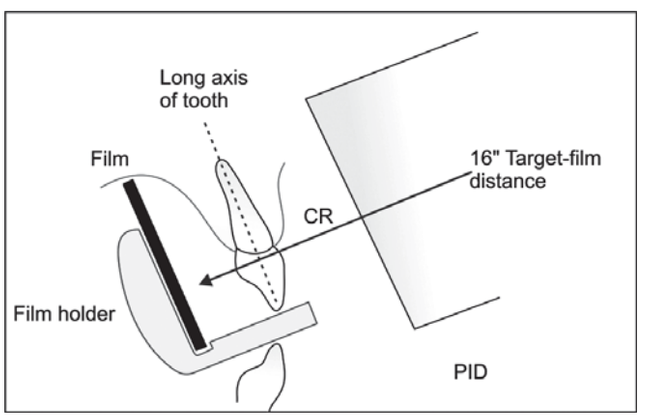
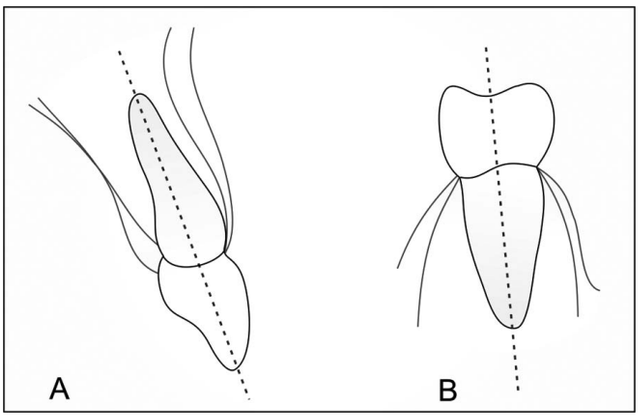


Fig. 11.8: Positions of the film, tooth and the central ray of the X-ray beam in the paralleling technique. The film and long axis of the tooth are parallel. The central ray is perpendicular to the tooth and the film. An increased target film distance (16 inches) is required



Figs 11.9A and B: A. The long axis of the maxillary incisor divides the tooth into two equal halves. **B.** The long axis of the mandibular premolar divides the tooth into two equal halves

A Film Holder is defined as a device that is used to position an intraoral film in the mouth and retain the film in position during exposure.

The film holder eliminates the need of the patient to stabilize the film.

Examples of commercially available Film Holders are:

- Rinn XCP (X = extension, C = cone, P = paralleling)
- Precision Film Holders.

  In both the above holders a face collimator can be incorporated along with an aiming ring.
- Stable Bite Blocks – these are disposable film holders.
- EEZEE- Grip Film Holder.
- Hemostat with bite block.

The reusable film holders must be sterilized following each use.

The holder having the aiming rings help in the alignment of the PID with the film and also help to reduce exposure to the patient.

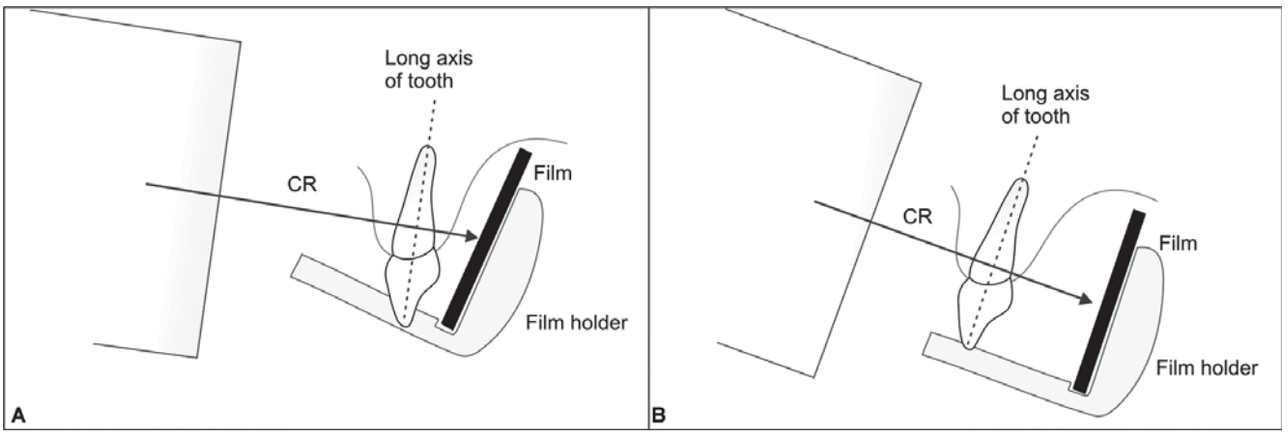
Film: Ideally the size of the film used will depend upon the teeth being radiographed.

Size 1 film is used for anterior teeth, as this is a narrow film.

Size 2 film is used for the posterior region.

Guidelines for Film Placement

- The white side of the film always faces the teeth.
- The film when used for anterior teeth is always placed vertically.
- The film when used for posterior teeth is always placed horizontally.
- The identification dot on the film is always placed in the slot of the film holder, or towards the occlusal end of the film.



Figs 11.10A and B: A. The film is placed close to the tooth and is not parallel to the long axis of the tooth. **B.** Increased object-film distance. The film is placed away from the tooth and is now parallel with the long axis of the tooth

- When placing the film in the mouth always lead with the apical end of the film and rotate the film holder.
- When placing the film holder, always place the film away from the teeth and towards the middle of the oral cavity.
- When positioning the film holder, always center the film over the area or tooth to be examined.
- When positioning the film holder ask the patient to "slowly close" on the bite block, always make certain that the bite block is stabilized by the teeth and not the lips.

Patient Positioning for Paralleling Technique

- Briefly explain the procedure to the patient before you begin.
- Adjust the chair so that the patient is positioned upright in the chair. The level of the chair must be adjusted to a comfortable working height for the dental surgeon.
- Adjust the head rest to support and position the patient's head. The patient's head must be positioned so that the upper arch (occlusal plane) is parallel to the floor and the midsagittal (mid line) plane is perpendicular to the floor.
- Secure the lead apron and thyroid collar on the patient.
- Remove all objects from the mouth (e.g. dentures, retainers, chewing gum, etc.) that may interfere with the film exposure. Eye glasses must be removed also.

There are five basic rules to be followed in the paralleling technique:

- *Film placement*: The film must be positioned to cover the prescribed area of the teeth to be examined.
- *Film position*: The film must be positioned parallel to the long axis of the tooth. The film, in the film holder must be placed away from the teeth and towards the middle of the oral cavity.
  - i. *Maxillary Incisors and Canines*—The film packet is positioned sufficiently posteriorly, to enable its height to be accommodated in the vault of the palate.
  - ii. *Maxillary Premolars and Molars*—The film packet is placed in the midline of the palate, again to accommodate its height in the vault of the palate.
  - iii. *Mandibular Incisors and Canines*—The film packet is positioned in the floor of the mouth, roughly in line with the lower canines or first premolars.
  - iv. Mandibular Premolars and Molars—The film packet is placed in the lingual sulcus next to the appropriate teeth.
- The holder is rotated so that the teeth under investigation are touching the block.

A cottonwool roll is placed on the reverse side of the bite block, to help keep the tooth and the film packet parallel, and the film holder more comfortable for the patient.

The patient is requested to bite gently together, to stabilize the holder in position.

The lower locater ring is moved down the indicator rod until it is just in contact with the patient's face. The correct focal spot to film distance is determined as the long cone is aligned with the locator ring. This automatically sets the vertical and horizontal angles and centers the X-ray beam on the film packet.

- i. *Vertical angulation*: The central ray of the X-ray beam must be directed perpendicular to the film and the long axis of the tooth.

ii. *Horizontal angulation*: The central ray of the X-ray beam must be directed through the contact areas between the teeth (Fig. 11.11).

iii. *Film exposure*: The X-ray beam must be centered on the film to ensure that all areas of the film are exposed. Failure to center the X-ray beam results in a partial image on the film or a 'cone-cut'.

- The exposure is made.

  Specific positionings for different areas of the mouth, and the resultant radiographs are shown in Figs 11.12 to 11.20a.

Advantage of Long Cone Technique

- *Accuracy*: The paralleling technique produces an image that has dimensional accuracy, (A profile view of the tooth with buccal and lingual roots projected in their normal respective lengths and buccal and lingual cusps correctly related on the same plane.) the image is very representative of the actual tooth.

  The radiographic image is free of distortion and exhibits maximum detail and definition.

  There is no overlap of related structures (e.g. the zygomatic shadow), all shadows of anatomical structures are cast in their proper anatomic position.

  This accuracy is due to:
  - Increased source film distance.
  - Object and film are parallel to each other.
  - Central ray strikes perpendicular to the long axis of the tooth and film.
  - Though the object film distance is increased, it is compensated by increased source film distance and therefore there is decreased enlargement.
  - The increased kVp, to reduce exposure time, as the source film distance is increased, helps by reducing secondary and unwanted, short wave length radiations.
- *Simplicity*: This technique is simple and easy to learn and use. The film holder with a beam alignment device eliminates the need for all dental surgeons to determine horizontal and vertical angulations and also eliminates chances of dimensional distortion and coning off.
- *Duplication*: This technique is easy to standardize and can be accurately duplicated or repeated, when serial radiographs are indicated. As a result comparison of serial radiographs exposed using this technique have great validity.
- Facial screens can be used.
- There is decreased secondary radiation.
- The radiographs produced give;
  - An excellent bone level assessment.
  - No elongation or foreshortening seen in the periapical region.
  - Inter proximal caries is clearly indicated.
- The shadow of the zygomatic bone appears above the apices of the molar teeth.
- The periodontal bone levels are well represented.
- The periapical tissues are accurately shown with minimal foreshortening or elongation.
- The crowns of the teeth are well shown enabling detection of proximal caries.
- The relative positions of the film packet, teeth and X-ray beam are always maintained, irrespective of the position of the patient's head. This is useful for handicapped and compromised patients.

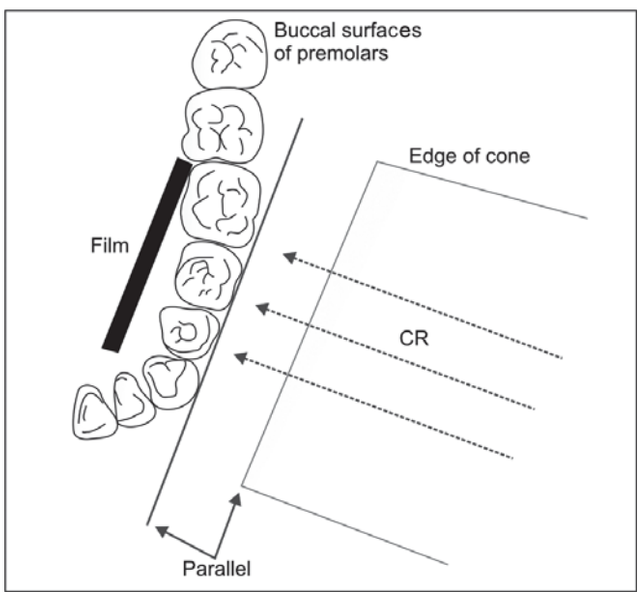
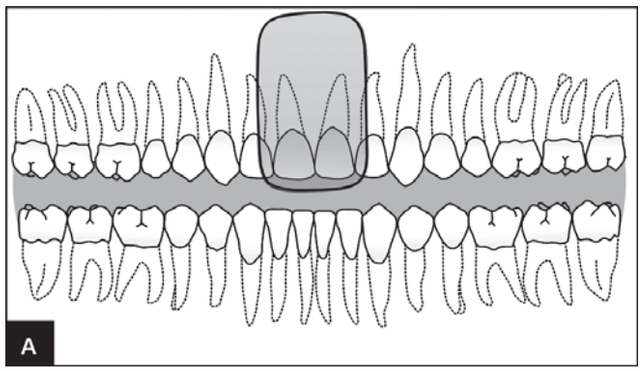


Fig. 11.11: In this diagram the X-rays pass through the contact areas of the premolars because the central ray is directed through the contacts and perpendicular to the film. If the central ray is not directed through the contacts, overlap of the premolar contact occurs

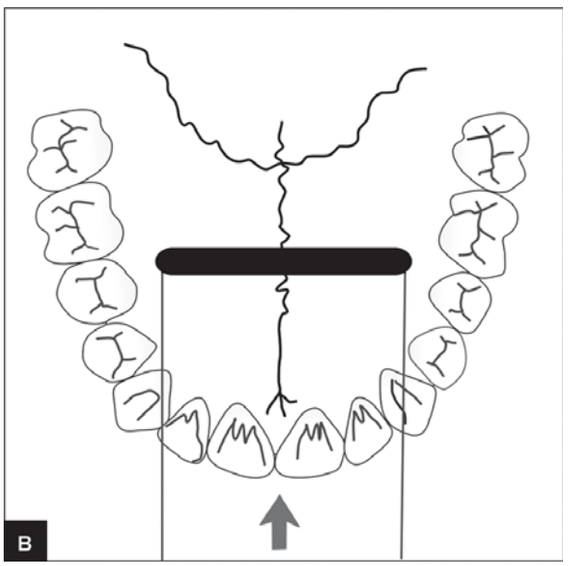
Disadvantage of Long Cone Technique

The primary disadvantage is that of film placement and patient discomfort.

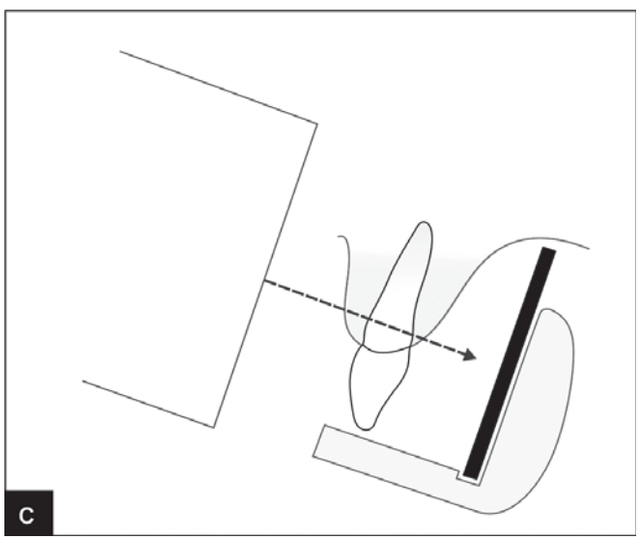
- *Film placement*: The film holding device is difficult to place and adjust especially in child patients and adults with a small mouth or shallow palate.
- Positioning the holders within the mouth can be difficult for inexperienced operators.



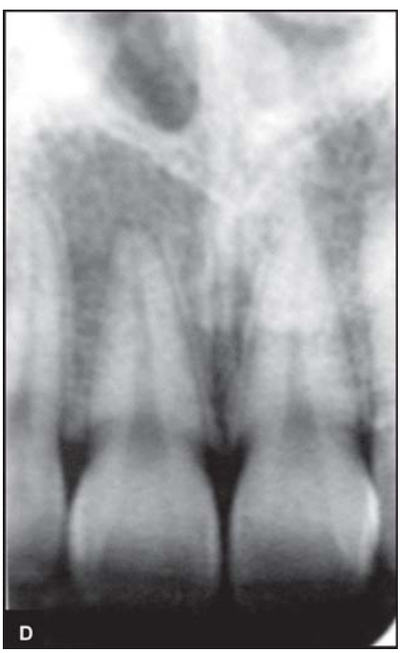
A. Image field – The field of view on these radiographs (shaded area) should include both central incisors and their periapical areas



B. Film placement – Should be placed at the level of the second premolars or first molars, the long axis should be parallel to the long axis of the maxillary central incisors

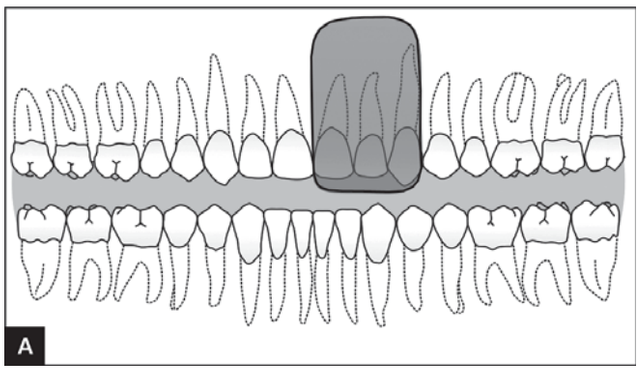


C. Projection of the central ray- directed high on the lip, in the midline, just below the septum of the nostril. Through the contact point of the central incisors and perpendicular to the plane of the film and roots of the teeth. Because the axial inclination of the maxillary incisors is about 15° to 20°, the vertical angulation of the tube should be at the same positive angulation

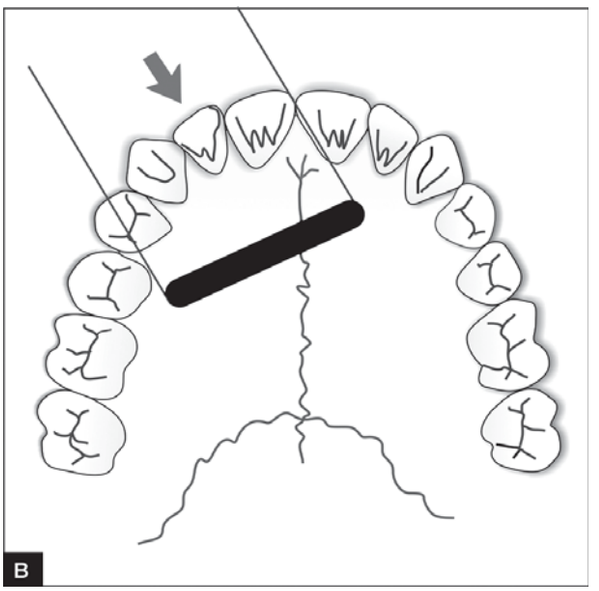


D. Radiograph of maxillary central incisors

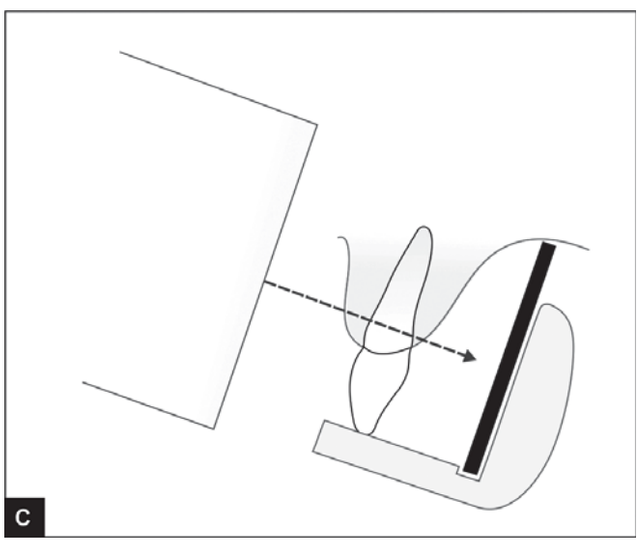
Fig. 11.12: Long Cone Technique for Maxillary Central Incisor



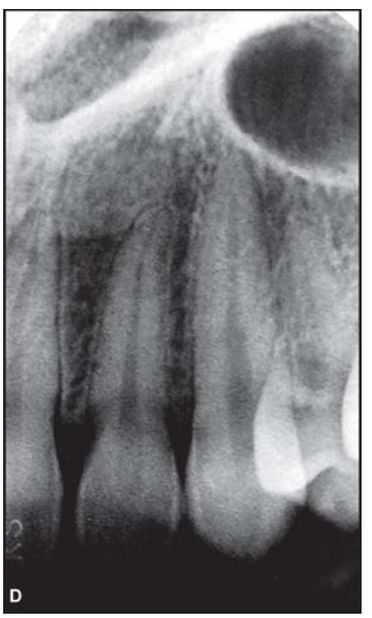
A. Image field – The field of view on these radiographs (shaded area) should show the lateral incisors centered on the radiograph. Include the mesial interproximal area with the distal aspect of the central incisor on the radiograph so that no overlap is possible



B. Film placement – should be placed parallel to the long axis and the mesiodistal plane of the maxillary lateral incisors

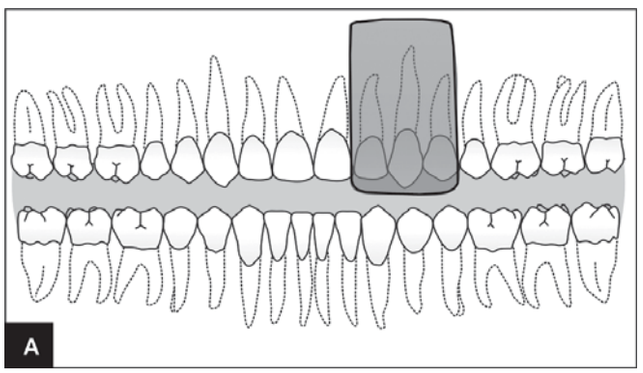


C. Projection of the central ray—Directed high on the lip, about 1cm from the midline. Through the middle of the lateral incisors, with no overlapping of the margins of the crowns at the interproximal space on its mesial aspect. Do not attempt to visualize the distal contact with the canine

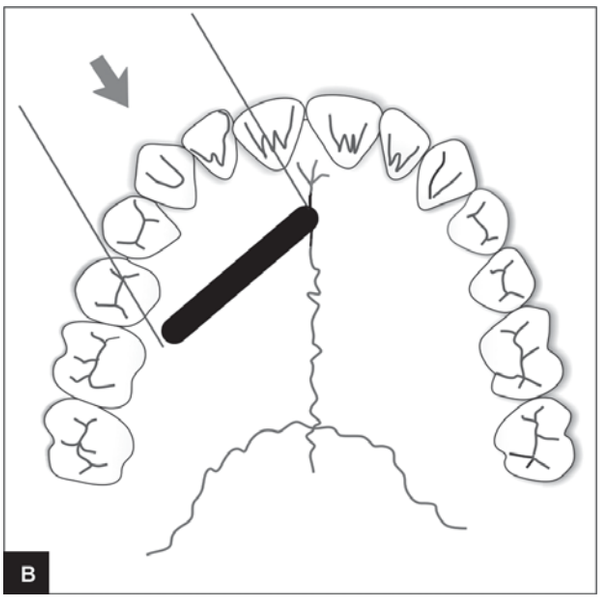


D. Radiograph of maxillary lateral incisor

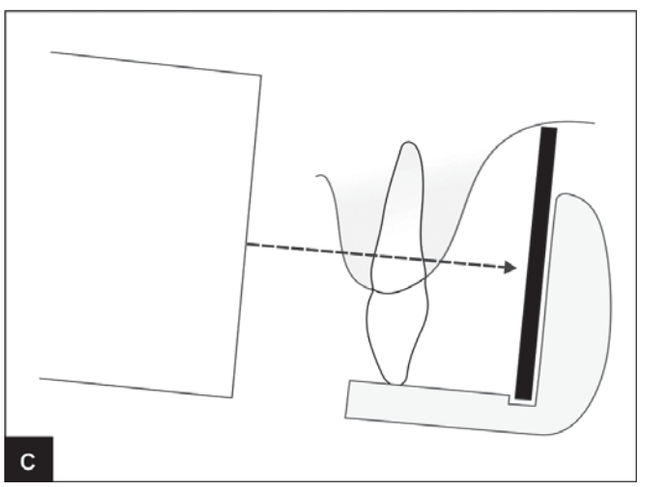
Fig. 11.13: Long Cone Technique for Maxillary Lateral Incisor



A. Image field – The field of view on these radiographs (shaded area) should demonstrate the entire canine, with its periapical area in the midline of the radiograph



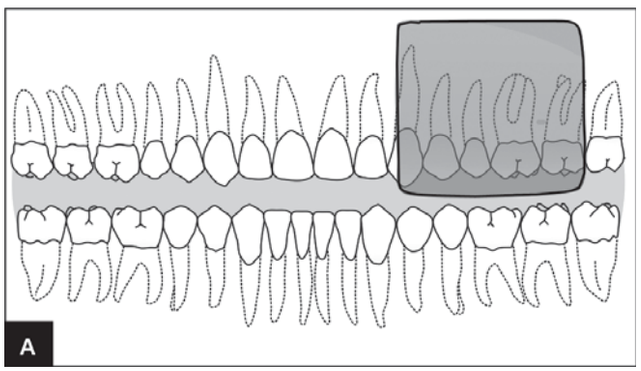
B. Film placement – should be placed against the palate, well away from the palatal surface of the teeth. Orient the film packet with its anterior edge at about the middle of the lateral incisor and its long axis parallel with the long axis of the canine



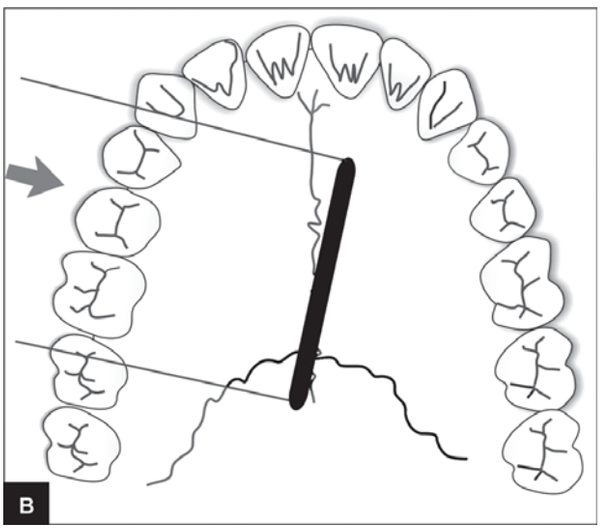
C. Projection of the central ray—Directed through the canine eminence, at the intersection of the distal and inferior borders of the ala of the nose, through the mesial contact of the canine

D. Radiograph of maxillary canine

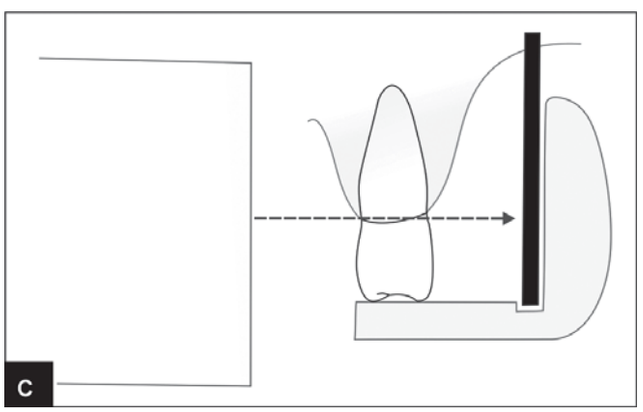
Fig. 11.14: Long Cone Technique for Maxillary Canine



A. Image field – The field of view on these radiographs (shaded area) should include the images of the distal half of the canine and the premolars, with room for at least the first molar



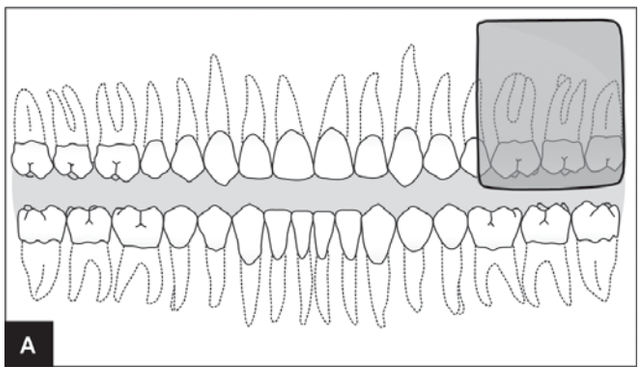
B. Film placement – Should be placed parallel with the occlusal plane and in the midline. It should cover the distal half of the canine, the premolars, and the first molar. The plane of the film should be nearly vertical to correspond with the long axis of the premolar teeth. (The long axis of the film should be approximately parallel to the mean buccal plane of the premolars)



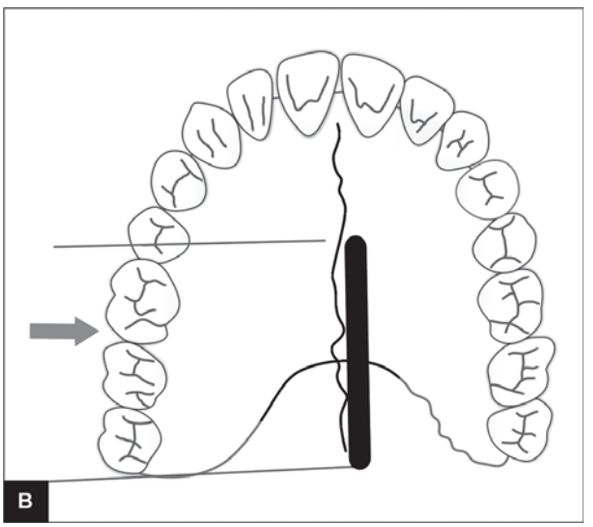
C. Projection of the central ray- Directed through the center of the second premolar root, approximately below the pupil of the eye

D. Radiograph of maxillary premolars

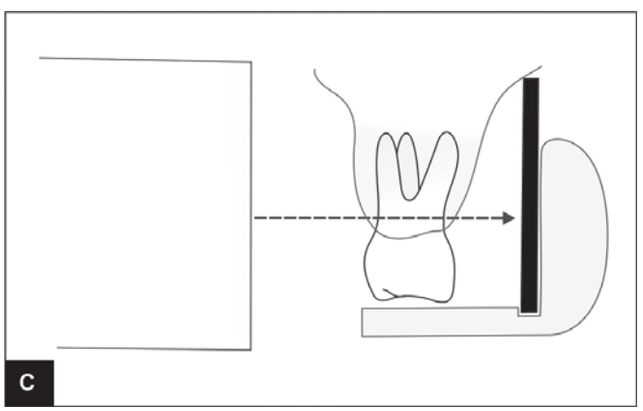
Fig. 11.15: Long Cone Technique for Maxillary Premolar



A. Image field – The field of view on these radiographs (shaded area) should include the images of the distal half of the second premolar, the three maxillary permanent molars, and some of the tuberosity



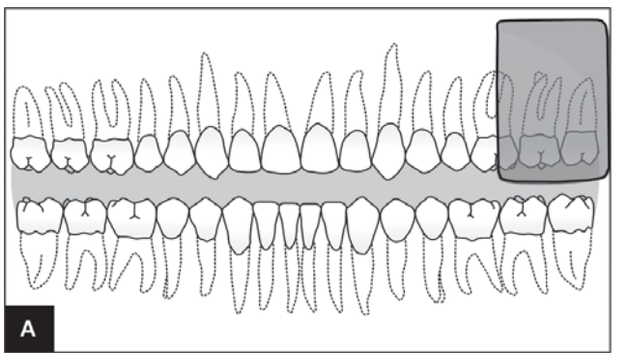
B. Film placement – Should be placed parallel with the occlusal plane and in the midline, far enough posterior to cover the first, second and third molar areas and some of the tuberosity.The anterior border should just cover the distal aspect of the second premolar



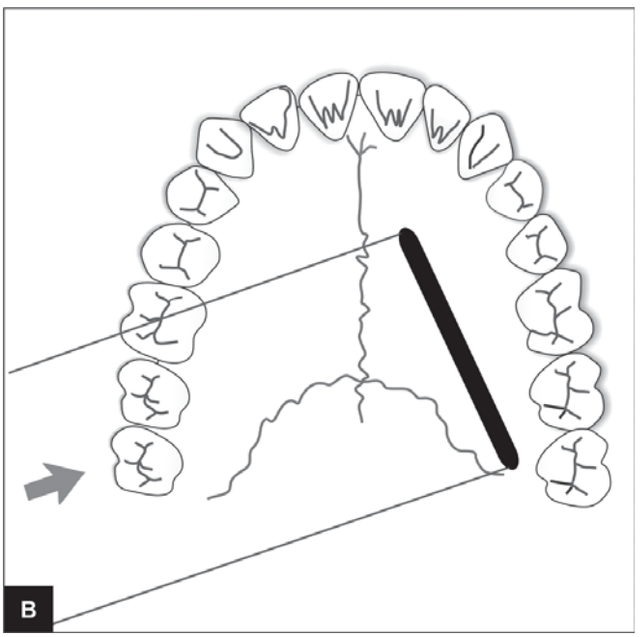
C. Projection of the central ray- Directed on the cheek below the outer canthus of the eye and the zygoma at the position of the maxillary second molar, perpendicular to the plane of the film

D. Radiograph of maxillary molars

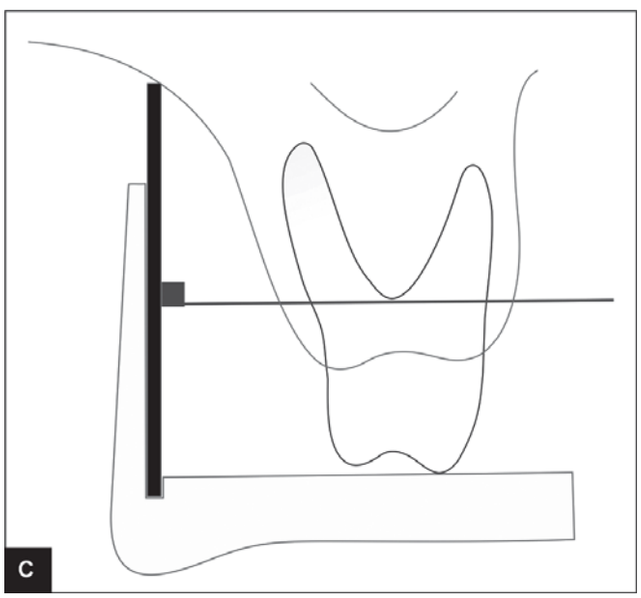
Fig. 11.16: Long Cone Technique for Maxillary Molar



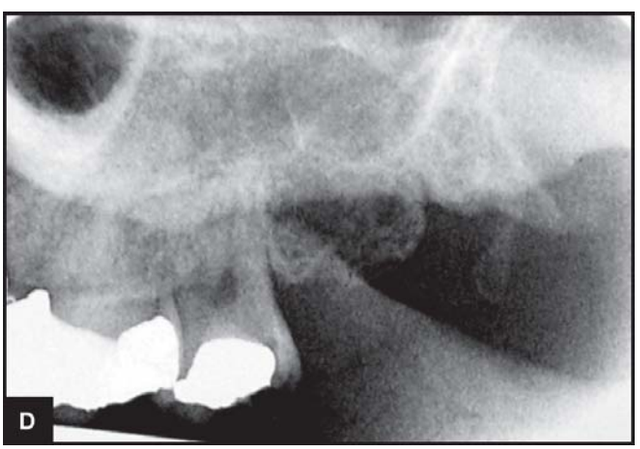
A. Image field – The field of view on these radiographs (shaded area) should include the images of the maxillary tuberosity area. To evaluate impacted teeth or pathological conditions in this bone area



B. Film placement – Should be placed in the midline, far enough posterior to cover the tuberosity and area distal to it. The film should be angled across the midline so that the posterior border is away from the teeth of interest and the anterior border is near the molars on the side being radiographed

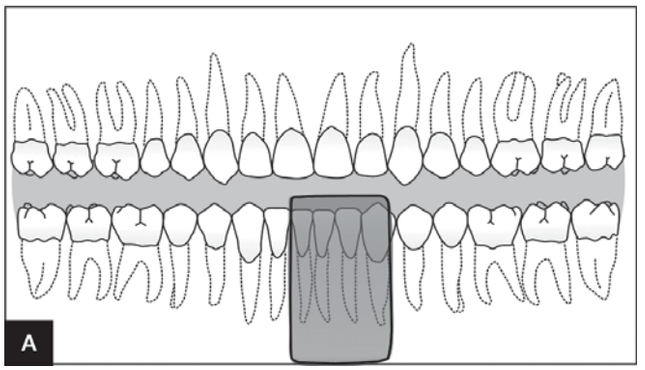


C. Projection of the central ray—Directed through the maxillary third molar region just below the middle of the zygomatic arch, distal to the lateral canthus of the eye, perpendicular to the angled film

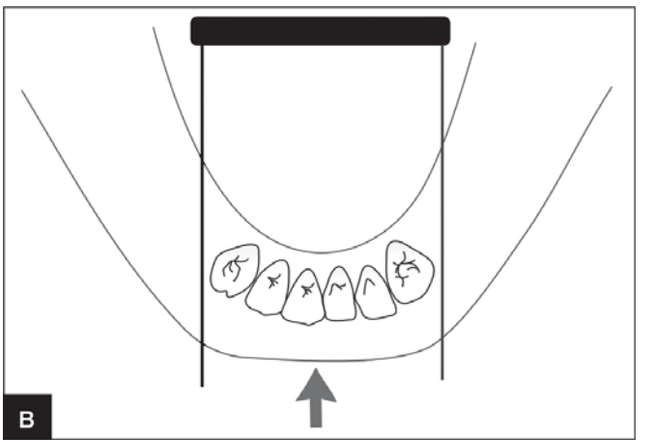


D. Radiograph of maxillary 3rd molar and tuberosity region

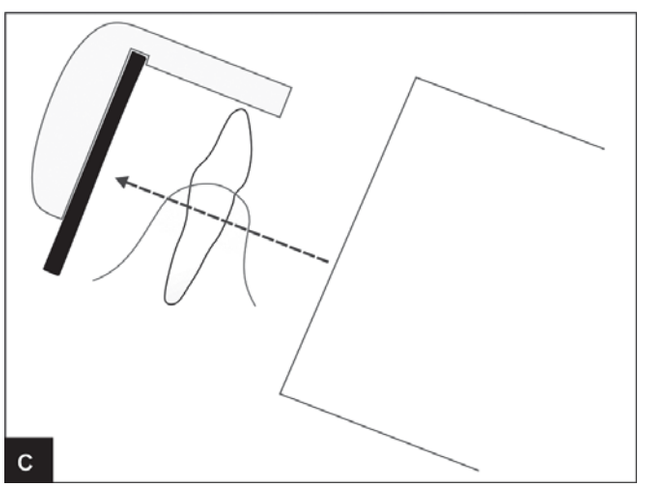
Fig. 11.16a: Long Cone Technique for Maxillary Distal Oblique Molar Projection



A. Image field – The field of view on these radiographs (shaded area) should include the images of the mandibular central and lateral incisors



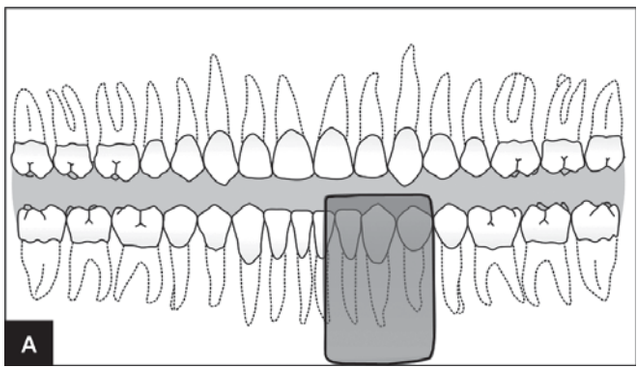
B. Film placement – Should be placed vertically behind the central and lateral incisors with the contact area centered and the lower border below the tongue. The film should be placed as far back posteriorly, usually between the premolars



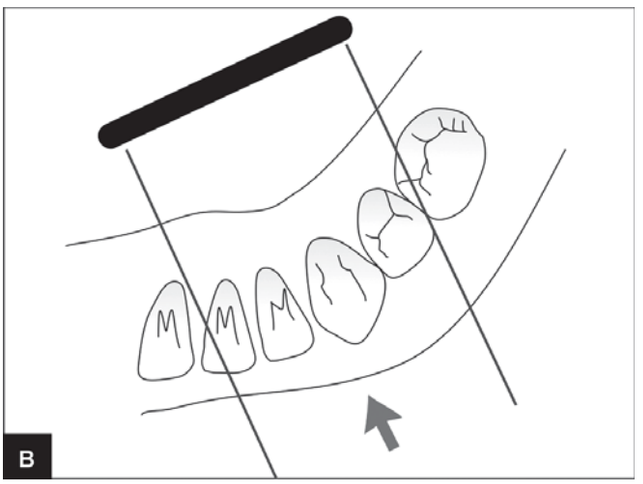
C. Projection of the central ray- Directed below the lower lip, about 1cm lateral to the midline, through the interproximal space between the central and lateral incisors

D. Radiograph of mandibular central and lateral

Fig. 11.17: Long Cone Technique for Mandibular Central and Lateral Incisors



A. Image field – The field of view on these radiographs (shaded area) should include the images of the entire mandibular canine and its periapical area



B. Film placement – should be placed vertically and the canine in the middle of the film. The film should be placed as far lingually as the tongue and contralateral alveolar process permit

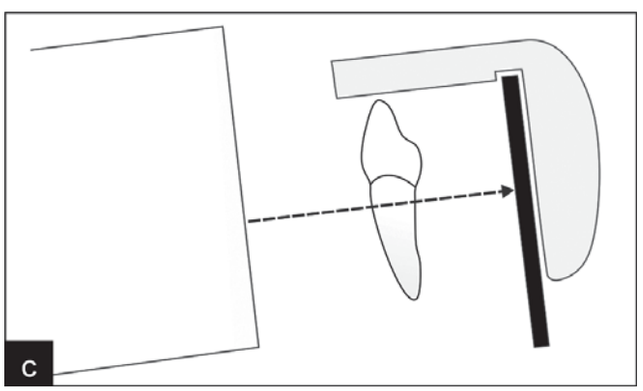


Fig. 11.18C: Projection of the central ray—Directed perpendicular to the ala of the nose, over the position of the canine, about 3 cm above the inferior border of the mandible, through the mesial contact of the canine

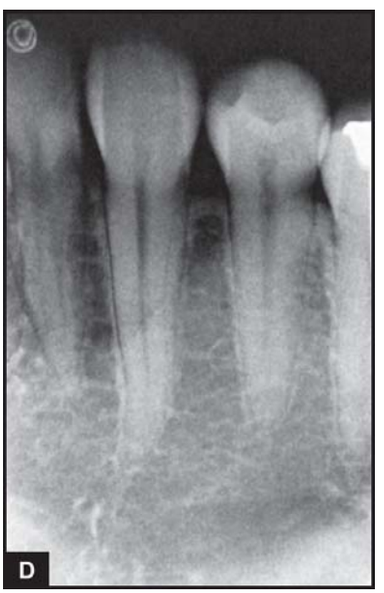
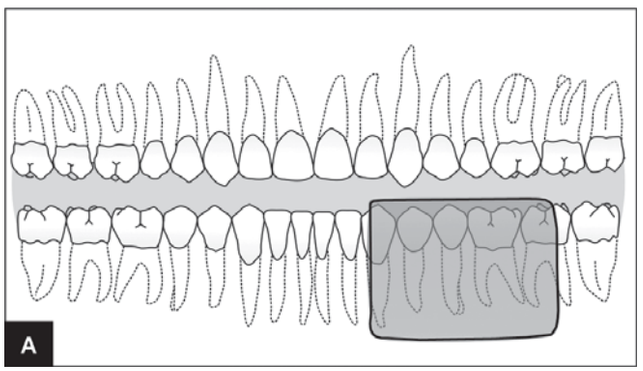
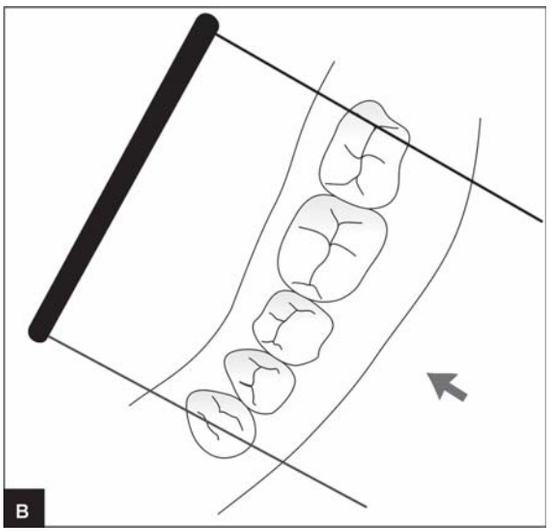


Fig. 11.18D: Radiograph of mandibular canine

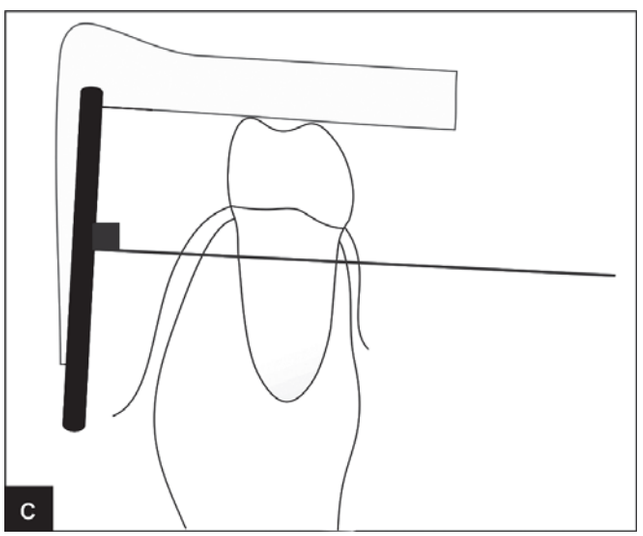
Fig. 11.18: Long Cone Technique for Mandibular Canine



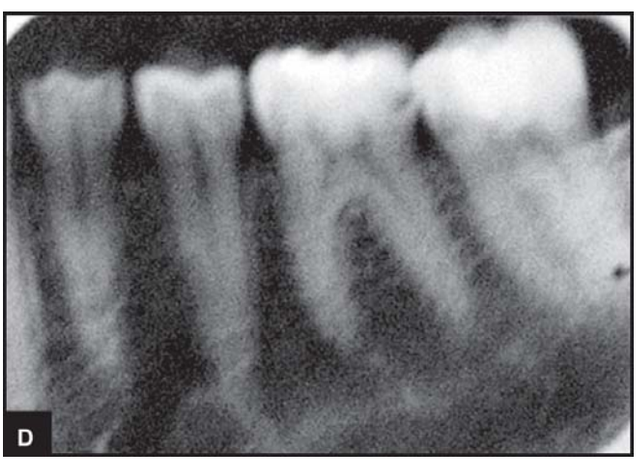
A. Image field – The field of view on these radiographs (shaded area) should include the images of the distal half of the canine, the two premolars, and the first molar



B. Film placement – should be placed horizontally, between the tongue and the teeth, with the anterior border near the midline of the canine

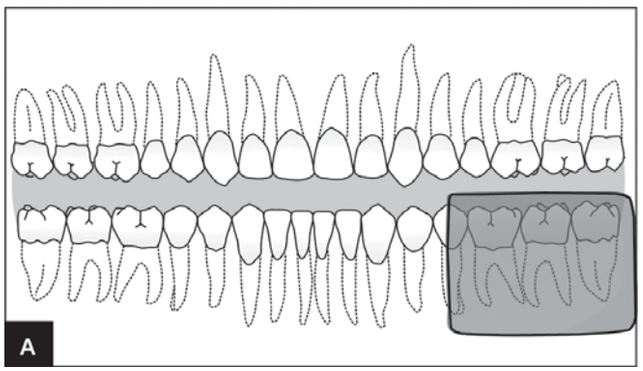


C. Projection of the central ray—Directed below the pupil of the eye and about 3 cm above the inferior border of the mandible, through the premolar contact area

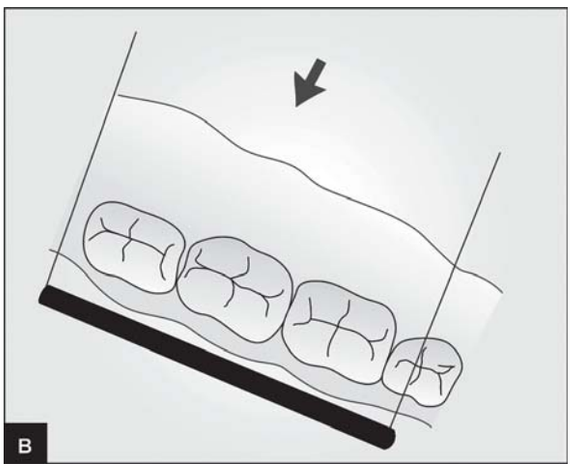


D. Radiograph of mandibular premolars

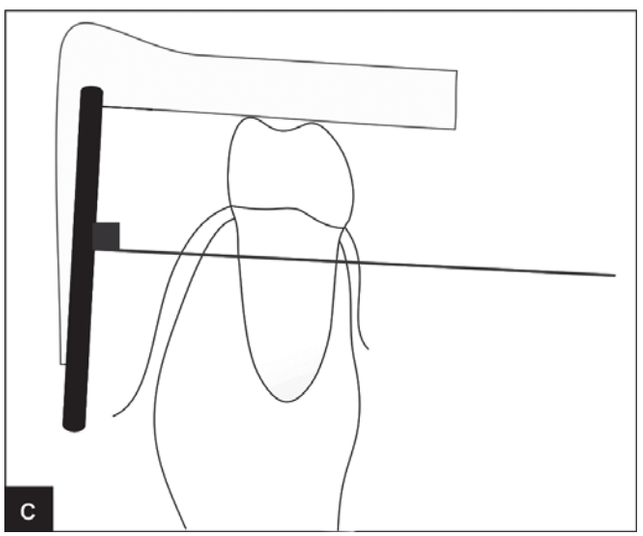
Fig. 11.19: Long Cone Technique for Mandibular Premolars



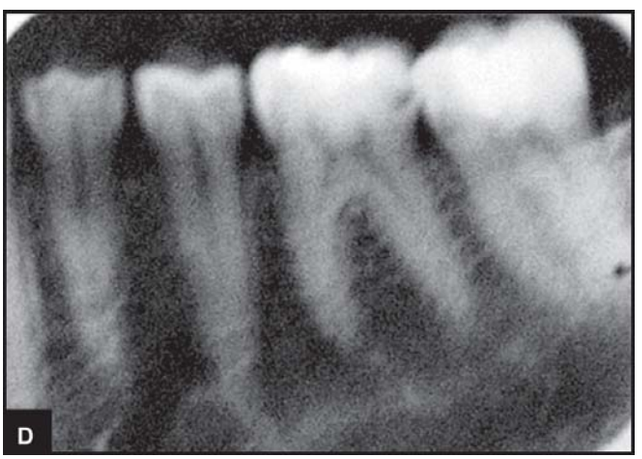
A. Image field – The field of view on these radiographs (shaded area) should include the images of the distal half of the second premolar, and the three mandibular molars



B. Film placement – should be placed horizontally, between the tongue and the teeth, with the anterior border near the middle of the second premolar

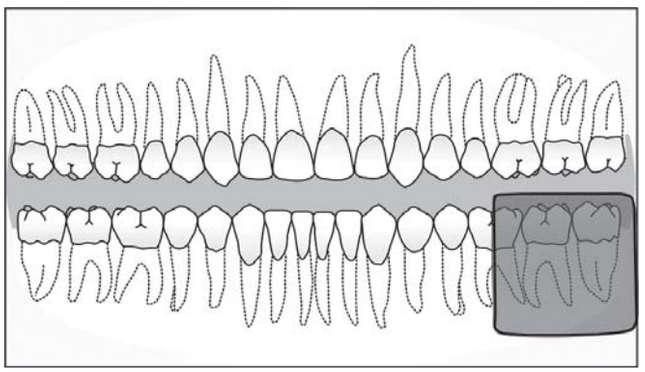


C. Projection of the central ray—Directed below the outer canthus of the eye and about 3 cm above the inferior border of the mandible, through the molar contact area. Because of the slight lingual inclination of the molars, the central ray may have a slight positive angulation

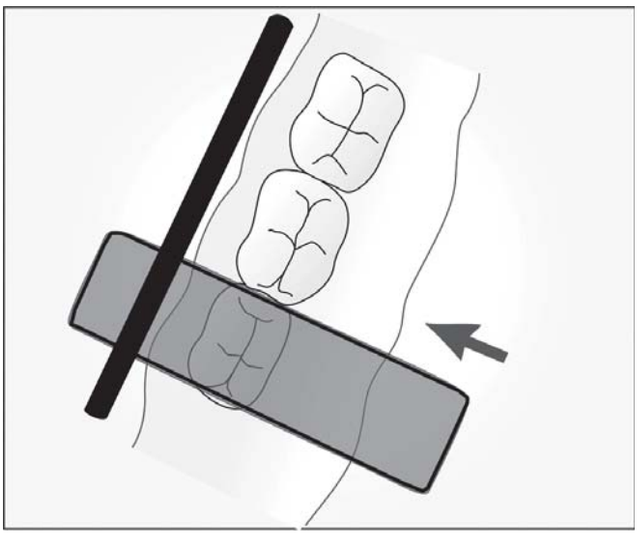


D. Radiograph of mandibular molars

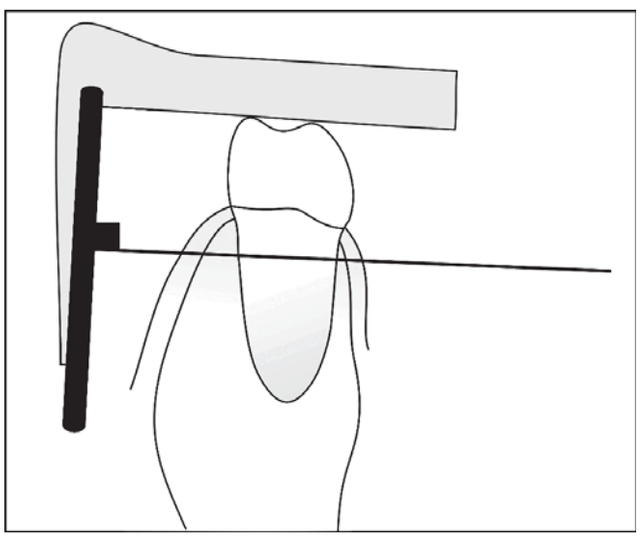
Fig. 11.20: Long Cone Technique for Mandibular Molars



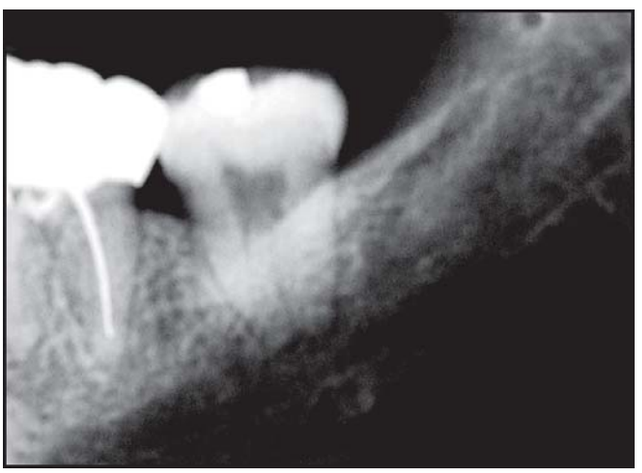
A. Image field – The field of view on these radiographs (shaded area) should include the images of the retromolar area of the mandible



B. Film placement – Should be placed horizontally, between the tongue and the teeth, as far posteriorly, with the posterior border of the film angled towards the midline



C. Projection of the central ray—Directed about 3 cm above the antegonial notch on the inferior border of the mandible, in line with the anterior border of the ramus. The beam is directed posterio-anteriorly, through the third molar, so that the more distal objects are projected anteriorly onto the film



D. Radiograph of third mandibular molar and retromolar area

Fig. 11.20a: Long Cone Technique for Mandibular Distal Oblique Molar Projection

- *Patient discomfort*: The film holding device may impinge on the oral soft tissues and cause discomfort and gagging.
- Object film distance is increased.
- The film should be parallel to the long axis of the tooth, only a 20° margin of error is considered permissible.
- In this technique there is an increase in exposure time as the distance between the target and patient is increased.
- The long cone is more space consuming and thus difficult to manage in a small dental office.
- Sometimes the apices of the teeth are very close to the edge of the film and the periapical area is not well appreciated.
- There is no particular advantage of using this technique in the lower molar region.
- Positioning the film in the third molar region can be difficult.
- The so called long cones which are marketed are sometimes short which leads to gross magnification of the image produced.
- With certain X-ray machines, (e.g. Philips Orallx) the heavy long cone unbalances the head which has to be frequently tightened or should have a counter balance put on the handle of the tube head.
- The holders need to be autoclavable.

B. *Angle Bisecting Technique*: is also called Short Cone Technique. It is based on the simple geometrical principle known as "the rule of isometry", (Fig. 11.21) which states that two triangles are equal if they have two equal angles and share a common side.

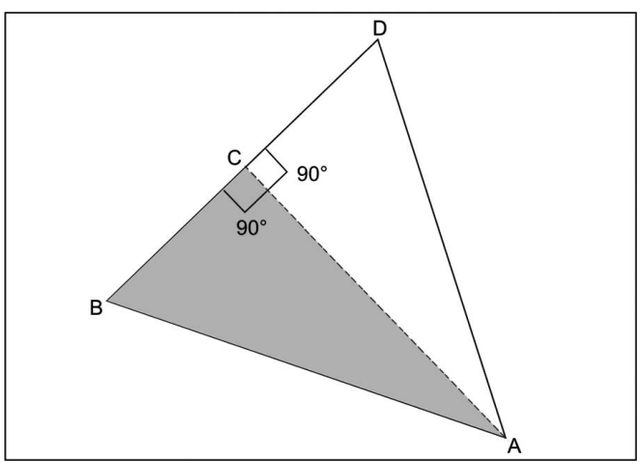


Fig. 11.21: Angle A is bisected by line AC. Line AC is perpendicular to line BD. Angle BAC is equal to angle DAC. Angle ACB is equal to angle ACD.
The rule of isometry, states that two triangles that have two angles that are equal and have a common side are equal triangles, therefore triangle BAC is equal to triangle DAC

In this technique the film is placed along the lingual surface of the tooth, and at the point where the film contacts the tooth, the plane of the film and the long axis of the tooth form an angle (Figs 11.22A to C).

The dental surgeon must visualize a plane that divides in half or bisects, the angle formed by the film and the long axis. This plane is termed the "imaginary bisector" and this bisector creates two equal angles and provides a common side for the two imaginary equal triangles.

The two imaginary triangles that result are right triangles and are congruent. The hypotenuse of one imaginary triangle is represented by the long axis of the tooth and the other hypotenuse is represented by the plane of the film.

When the rule of isometry is followed strictly, the radiographic image of the tooth is accurate (Fig. 11.23).

Film stabilization: In bisecting angle technique the film holding instruments or the patient's finger may be used to position and stabilize the film.

The commercially available film holders are:

- Rinn BAI Instruments (B-bisecting, A-angle, I-instrument) these include a plastic bite block, plastic aiming rings and metal indicator arms. To reduce radiation to the patient, snap on ring collimators may be added to the plastic aiming rings. These instruments aid in determining the horizontal and vertical angulations and minimise distortion from film bending and cone cutting.
- Stable Bite Block (Rinn Corporation) this can be used in both long and short cone technique. In Short Cone Technique, the scored front section is removed and film is placed as close to the teeth as possible. This is a disposable device.
- EEZEE Grip Film Holder (Rinn Corporation) also called Snap-A-Ray, this is also used for both the intraoral periapical techniques.

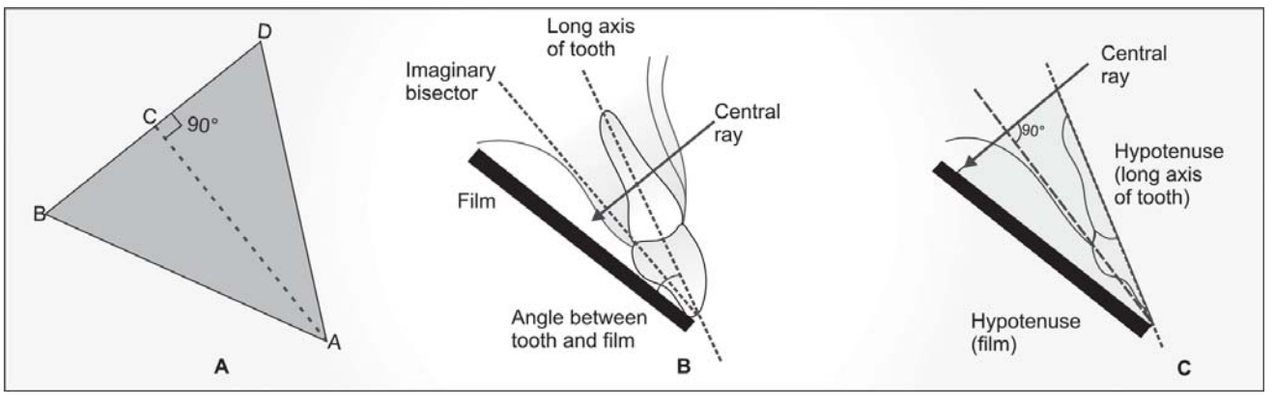
Finger Holding Method or the Digital Method: Here the patients finger or thumb is used to stabilize the film. The finger or the thumb is always placed behind the film and teeth.

The patient's thumb is used to position maxillary films and the index finger to stabilize mandibular films.

The patient's left hand is used for exposures on the right side of the mouth and right hand is used for exposures on the left side of the mouth.

Disadvantages

- Patient's hand is in the path of the primary beam, thus leading to unnecessary exposure.



Figs 11.22A to C: A. The film (line BA) is placed along the lingual surface of the tooth. At the point where the film contacts the tooth, the plane of the film and the long axis of the tooth (DA) form an angle (BAD). The imaginary bisector divides the angle into two equal angles (BAC and DAC). The central ray (BD) is directed perpendicular to the imaginary bisector and completes the third side, (BC and CD) of the two triangles **B.** Bisecting technique showing the central ray directed at right angle to the imaginary bisector. **C.** The two imaginary triangles that result are right triangles and congruent. The hypotenuse of each triangle is represented by the long axis of the tooth and the plane of the film

- Patient may use excessive force to stabilize the film causing bending of the film which can cause image distortion.
- Patient may allow the film to slip from its position resulting in inadequate exposure of the prescribed area.
- Without the film holder and aiming ring, the dental surgeon may align the PID incorrectly, causing partial image or cone cut.

Films: The size 2 intraoral film is used.

Guidelines for Film Placement

- White side of the film always faces the teeth.
- Anterior films always placed vertically.
- Posterior films always placed horizontally.

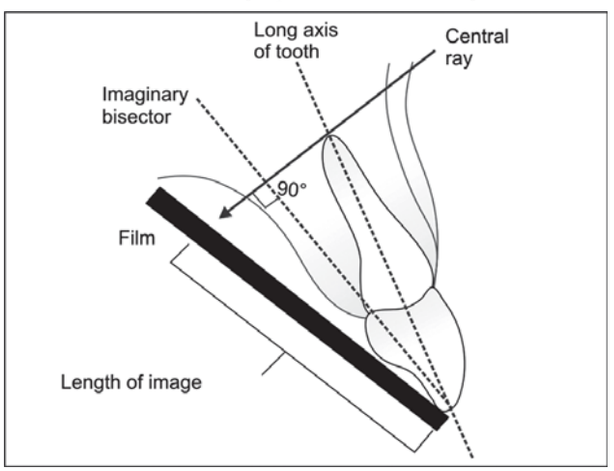


Fig. 11.23: The image on the film is equal to the length of the tooth when the central ray is directed at 90° to the imaginary bisector. A tooth and its radiographic image will be equal in length when two triangles are formed that share a common side (imaginary bisector)

- The incisal or occlusal edge of the film must extend approximately 1/8th inch beyond the incisal or occlusal surface of the tooth.
- When positioning the film always center the film over the area to be examined or the tooth under consideration.
- When positioning the patient's finger to stabilize the film, instruct the patient to "gently" push the finger against the lingual/palatal surface of the tooth (Fig. 11.24).

Patient Positioning for Bisecting Angle Technique

- Briefly explain the radiographic procedure to the patient before the procedure begins.

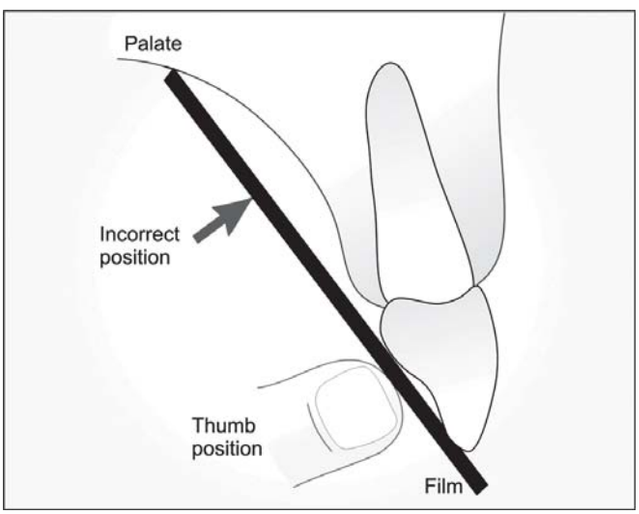


Fig. 11.24: Correct position of thumb and incorrect thumb position area that will produce curved film

- Position the patient upright in the chair. The chair level should be adjusted to a comfortable working height.
- Adjust the head rest to support the patient's head. The patient's head must be so positioned so that the arch being radiographed is parallel to the floor and the midsagittal plane is perpendicular to the floor.
- Place and secure the lead apron and thyroid collar over the patient.
- Remove all objects from the patient's mouth (e.g. dentures, retainers, chewing gum, etc.) that may interfere with film exposure. Eye glasses must also be removed.

PID Angulations

In bisecting angle technique the PID angulations are critical.

Angulation is a term used to describe the alignment of the central ray of the X-ray beam in the horizontal and vertical planes.

These angulations can be varied by moving the PID in either a horizontal or vertical direction.

The use of the bisecting angle instruments with aiming rings dictates the proper PID angulations. However, when finger holding method is employed the dental surgeon must determine the horizontal and vertical angulations.

Horizontal angulations: Refers to positioning of the tube head and direction of the central ray in a horizontal or side-to-side plane. This is the same for all techniques, be it Long Cone, Bisecting Angle or Bite Wing.

The correct horizontal angulation is achieved by directing the central ray perpendicular to the curvature of the arch and through the contact areas of the teeth.

As a result the contact area on the radiograph appear 'opened' (Fig. 11.25).

If the horizontal angulation is incorrect it results in overlapped (unopened) contact areas, in which inter proximal areas of the teeth cannot be evaluated (Fig. 11.26).

Vertical angulations: Refers to the positioning of the PID in a vertical or up and down plane.Vertical angulation is measured in degrees and is registered on the outside of the tube head (Figs 11.27A and B). The vertical angulation differs according to the technique used (Fig. 11.28).

a. In Long Cone Technique, it is perpendicular to the film and the long axis of the tooth.
b. In Short Cone Technique, the vertical angulation is determined by the imaginary bisector. The central ray is directed perpendicular to the imaginary bisector.
c. In Bite Wing Technique, the vertical angulation is predetermined. The central ray is directed at +10 degrees to the occlusal plane.

Correct Vertical Angulations result in a radiographic image that has the same length as the tooth. Some recommended Vertical Angulations for the Bisecting Angle Technique are:

	Maxillary vertical angulation in degrees		*Mandibular vertical angulation in degrees*	
	Universal standard	*Indian standard*	*Universal standard*	*Indian standard*
Canines	+45 to +55	+45	–20 to –30	–25
Incisors	+40 to +50	+45	–15 to –25	–20
Premolars	+30 to +40	+30	–10 to –15	–15
Molars	+20 to +30	+30	–5 to 0	–10 to 0

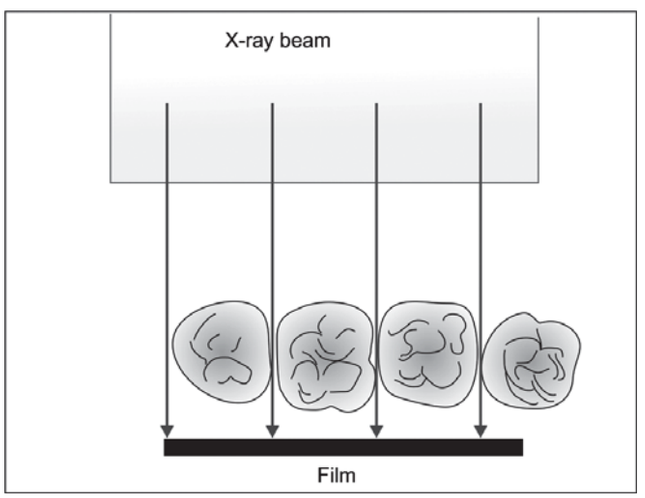


Fig. 11.25: Correct horizontal angulation

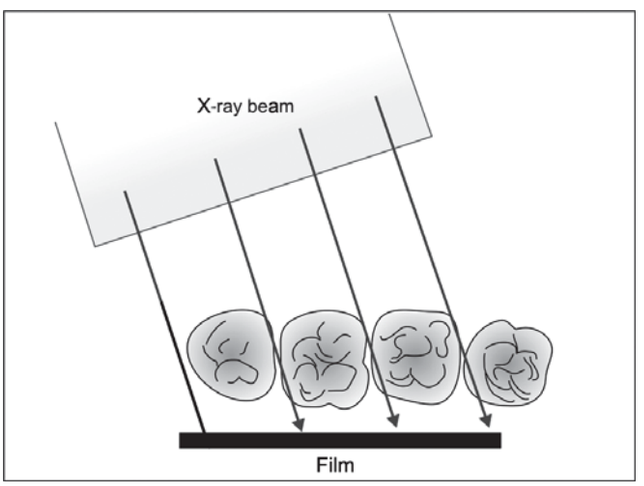


Fig. 11.26: Incorrect horizontal angulation

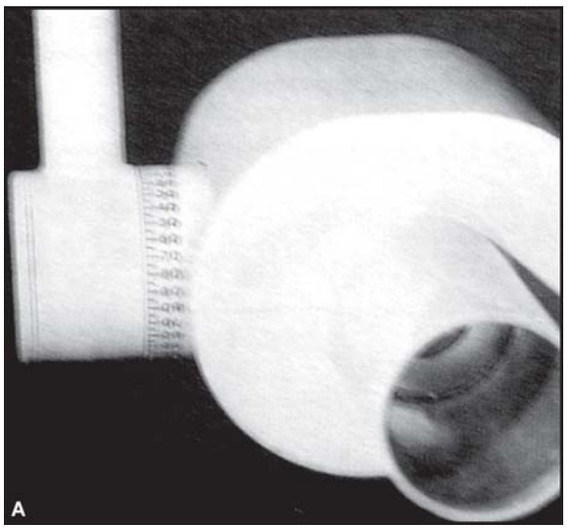


Fig. 11.27A: Vertical angulation is measured in degrees on the outside of the tube head

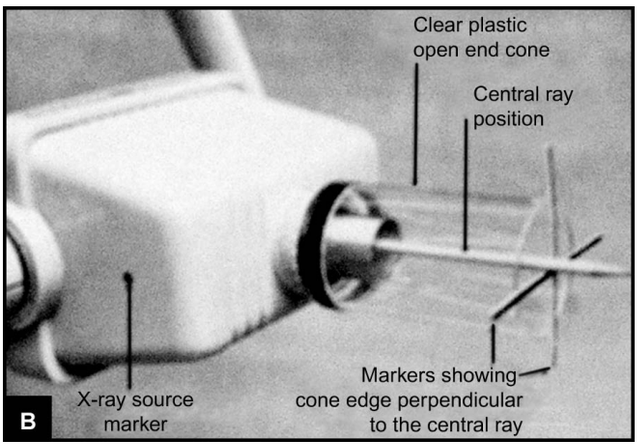


Fig. 11.27B: X-ray tube head showing X-ray source location and beam locating open end cone. Note the line on any surface end of cone is always perpendicular to central ray

Incorrect vertical angulation results in a radiographic image that is not of the same length as the tooth. It may appear as:

- Foreshortened Image, that is the image of the teeth appears shortened. This is due to excessive vertical angulation or when the central ray is directed perpendicular to the plane of the film rather than perpendicular to the imaginary bisector (Figs 11.29A and B).
- Elongated Image, that is the image of the teeth appears too long. This is due to insufficient or flat vertical angulation or when the central ray is directed perpendicular to the long axis of the tooth rather than perpendicular to the imaginary bisector (Figs 11.30A and B).

Five basic rules that should be followed in bisecting angle technique:

1. *Film placement*: The film should be positioned to cover the prescribed area of teeth to be examined.
2. *Film position*: The film must be placed against the lingual surface of the tooth. The occlusal end of the film (indicated by the raised identification mark or dot) must extend approximately 1/8th inch beyond the incisal or occlusal surfaces (Fig. 11.31). The apical end of the film must rest against the palatal or alveolar tissues if the finger holding method is used to stabilize the film. The patient must be instructed to press the film gently against the cervical portion (where the crown meets the roots) of the tooth (Fig. 11.32).
3. *Vertical angulation*: The central ray of the X-ray beam must be directed perpendicular to the image of the bisector that divides the angle formed by the film and the long axis of the tooth.
4. *Horizontal angulation*: The central ray of the X-ray beam must be directed through the contact areas between the teeth.

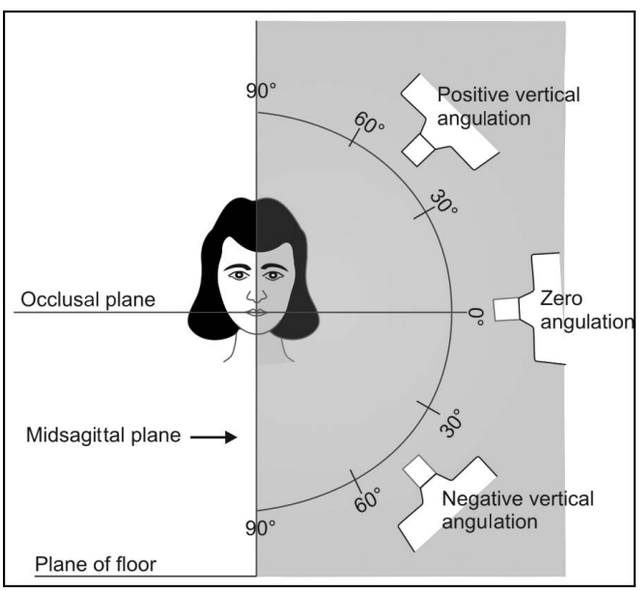


Fig. 11.28: All verticle angulations above the occlusal plane are termed positive. Verticle angulations below the occlusal plane are termed negative. Zero angulation is achieved when the PID and central ray are parallel to the floor

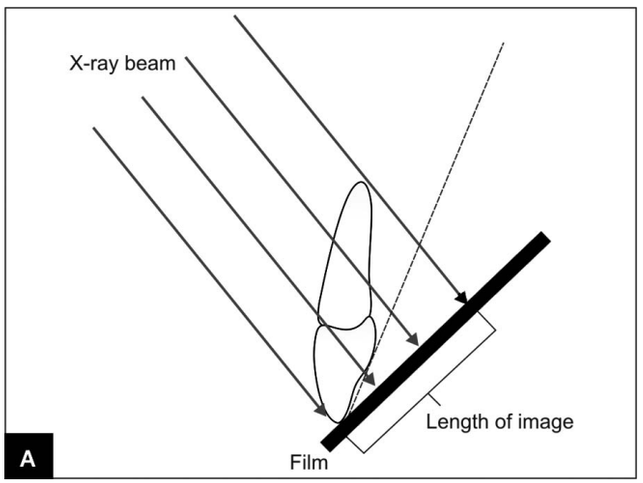


Fig. 11.29A: If the vertical angulation is too steep, the image on the film is shorter than the actual tooth

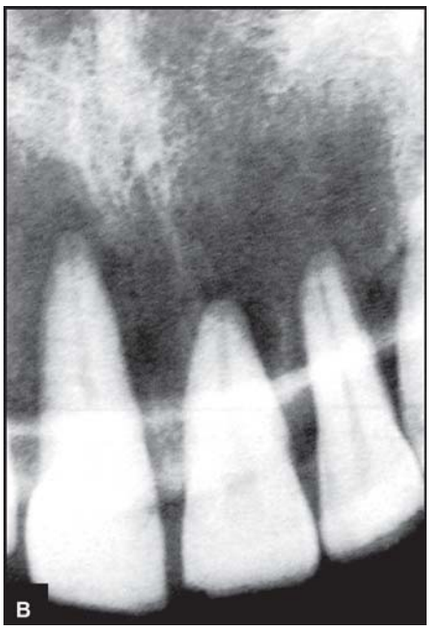


Fig. 11.29B: Foreshortened image

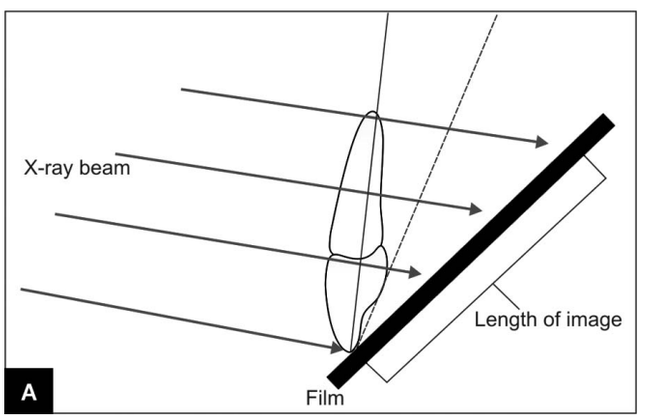


Fig. 11.30A: If the vertical angulation is too flat, the image on the film is longer than the actual tooth

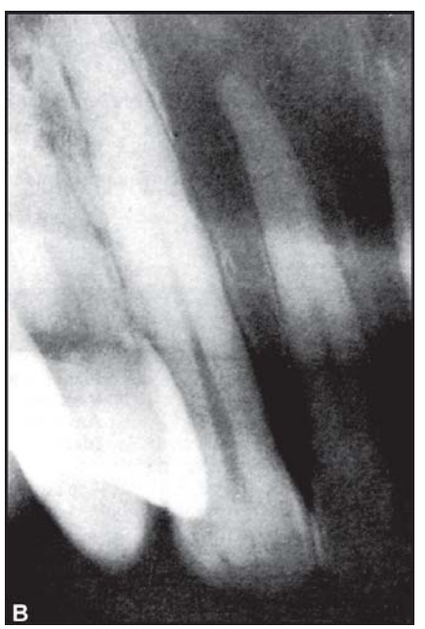


Fig. 11.30B: Elongated image

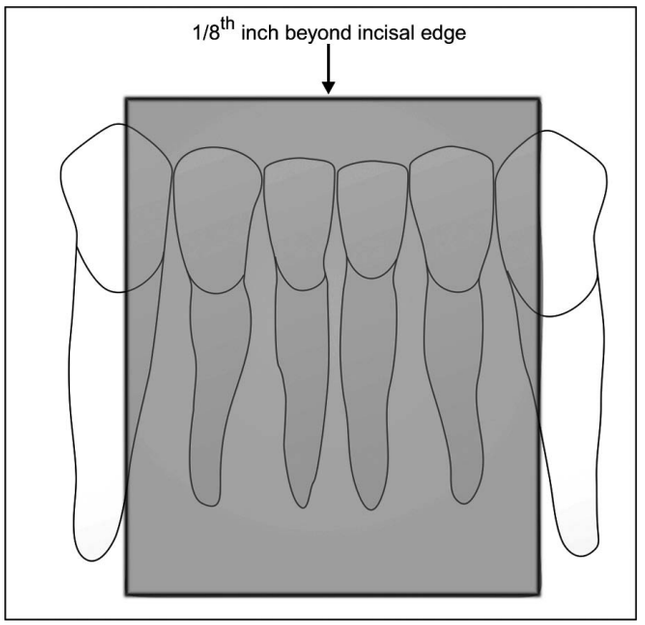


Fig. 11.31: Approximately 1/8th inch of the film must appear beyond the incisal edges of the teeth

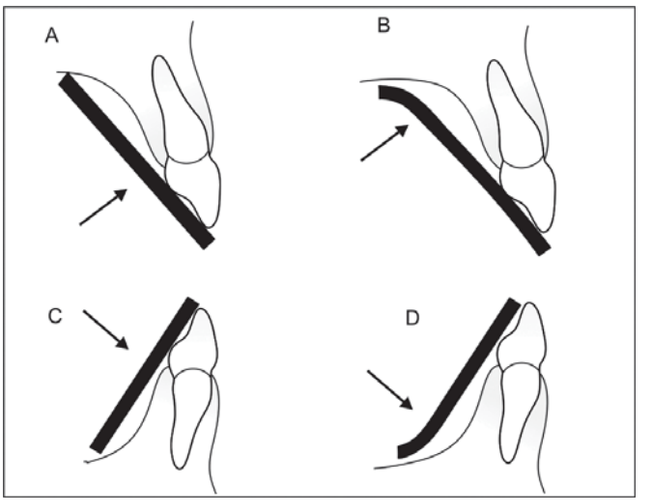


Fig. 11.32: Correct and incorrect finger placement (arrows indicate finger pressure holding film in place). **A.** Correct finger placement at crown gingival junction. **B.** Incorrect finger placement on palatal tissues. **C.** Correct finger placement at crown gingival junction. **D.** Incorrect finger placement on alveolar tissues

5. *Film exposure*: Center the X-ray beam on the film to ensure that all areas of the film are exposed. Failure to center the X-ray beam results in a partial image on the film or a cone cut.

External Guidelines for Directing the Central Ray (Figs 11.33 to 11.35).

a. The line of concentration for maxillary teeth is indicated along a line approximately 1/4th inch above the ala tragus line.
b. The line of concentration for mandibular teeth is indicated along a line approximately 1/4th inch above the lower border of the mandible.

Perpendicular Locating Lines (Fig. 11.36)

1. 11,21,31,41- point of intersection of a perpendicular line from the tip of the nose to A and B respectively.
2. 12,22,32,42- point of intersection of a perpendicular line from a point slightly distal to the tip of the nose to A and B respectively.
3. 13,23,33,43- point of intersection of a perpendicular line from the corner of the nose or inner canthus of the eye to A and B respectively.
4. 14,15,24,25,34,35,44,45- point of intersection of a perpendicular line from the pupil of the eye (Patient asked to look straight ahead) to A and B repectively.

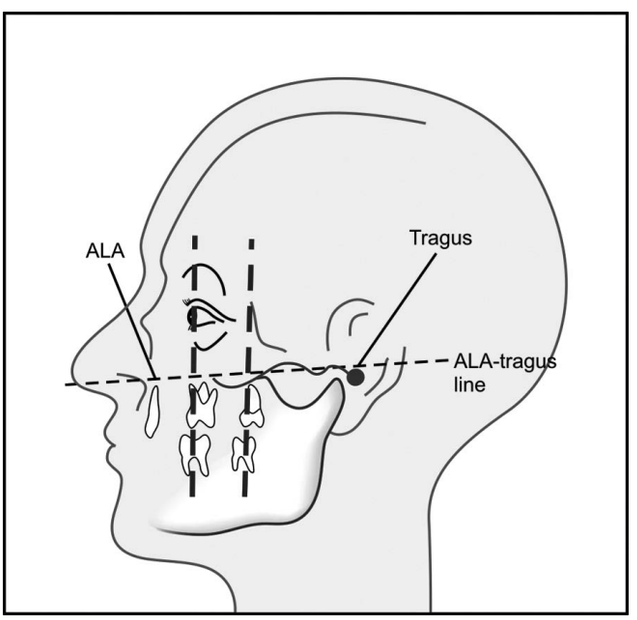


Fig. 11.33: Location of apices of teeth as seen from side of the patient

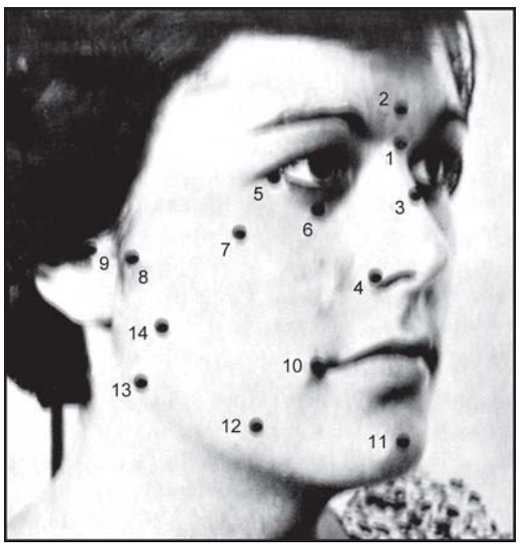


Fig. 11.34: Skin surface land marks useful in intraoral radiography— 1. Nasion, 2. Glabella, 3. Bridge of nose, 4. Ala of nose, 5. Outer canthus of the eye, 6. Mid point of infraorbital margin, 7. Zygomatic bone, 8. Temporomandibular articulation, 9. Tragus of the ear, 10. Corner of the mouth, 11. Symphysis mentii, 12. Body of the mandible, 13. Angle of the mandible, 14. Ramus of the mandible

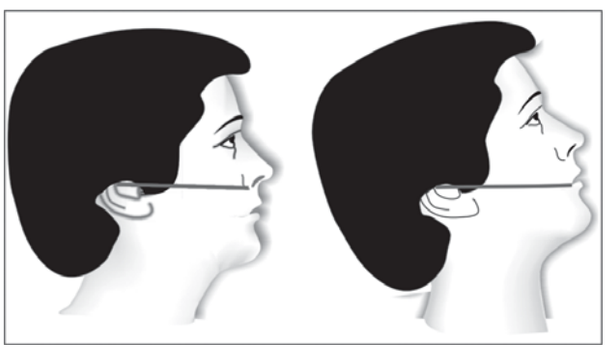


Fig. 11.35: Correct position of the Head for **A.** the maxillary teeth. **B.** the mandibular teeth

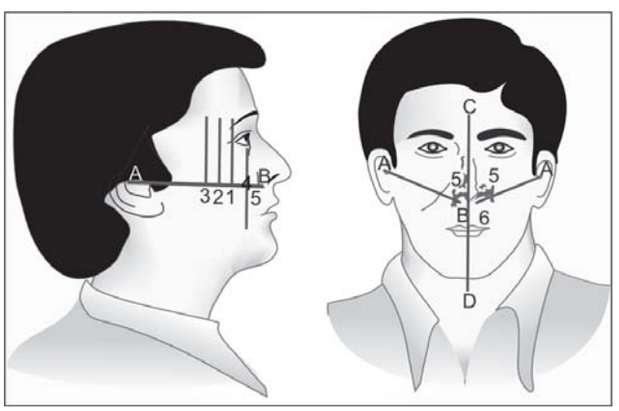


Fig. 11.36: External landmarks which help in the location of the point of entry of the central ray

5. 16,17,26,27,36,37,46,47- point of intersection of a perpendicular line from the outer canthus of the eye to A and B respectively.
6. 18,28,38,48 - point of intersection of a perpendicular line from distal to the outer canthus of the eye to A and B respectively.

The specific positioning for different areas of the mouth for bisecting technique are shown in the Figures 11.37 to 11.45a.

Modification in the Technique

Le Masters technique: Sometimes due to prominence of the malar bone, X-rays projected in the molar area at the normal angle result in the superimposition of the malar bone over the roots of the maxillary molars.

A cotton roll is fastened to the front side of the film. It rests against the palatal surface of the molars making the mean plane of the film more parallel to the plane of the tooth.

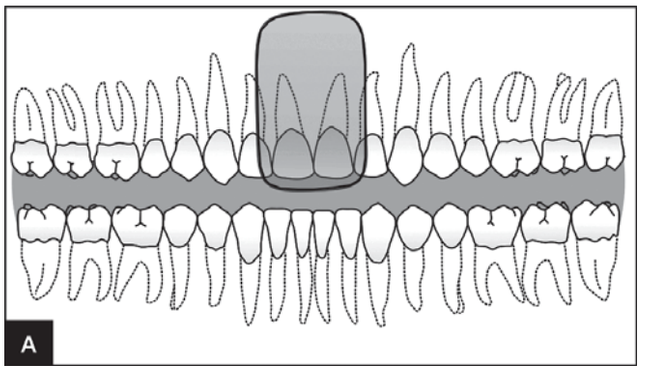
The vertical angulation is decreased so as to avoid the malar bone.

Advantage of Bisecting Angle Technique

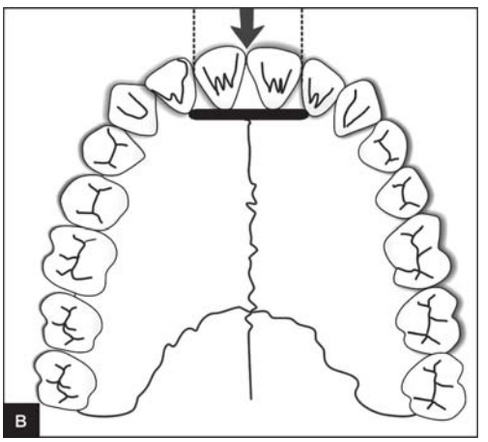
1. The primary advantage of this technique is that it can be used without a film holder when the anatomy of the patient (shallow palate, bony growths, sensitive mandibular premolar area) precludes the use of film holding device.
2. Positioning is reasonably comfortable, simple and quick for the patient in all areas of the mouth.
3. Decreased exposure time, as a short (8 inch) PID is used.
4. If all angulations are assessed correctly, the image of the tooth will be the same as the tooth itself and should be adequate (but not ideal) for most diagnostic purposes.
5. No sterlization of holders required, as they are not used.

Disadvantage of Bisecting Angle Technique

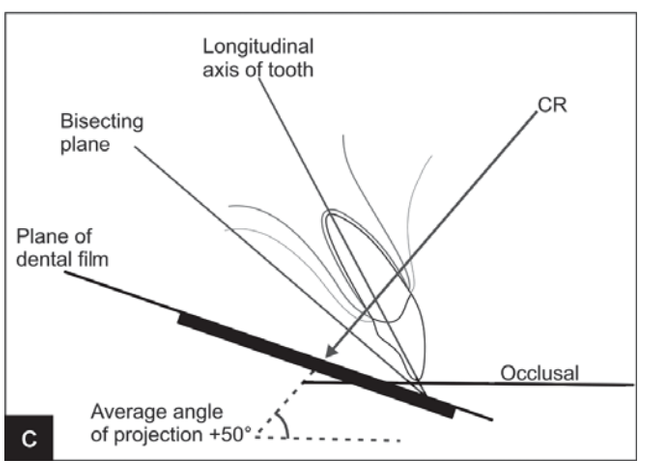
1. Image Distortion, this occurs due to;
   i. Use of short PID, as this results in the increase divergence of X-rays, leading to image magnification.
   ii. Due to the fact that the tooth (a 3 dimensional structure) is projected onto a film (a 2 dimensional structure), therefore structures futher away from the film appear more elongated than those closer to the film.



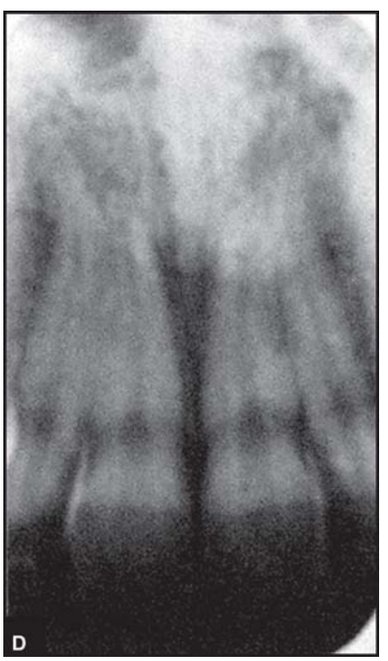
A. Image field—Should include both central incisors



B. Film placement—The film is placed behind the maxillary central incisors in line with the midline of the arch. The film is placed with the superior border on the palate and the inferior border extending just beyond the incisal edges of the teeth

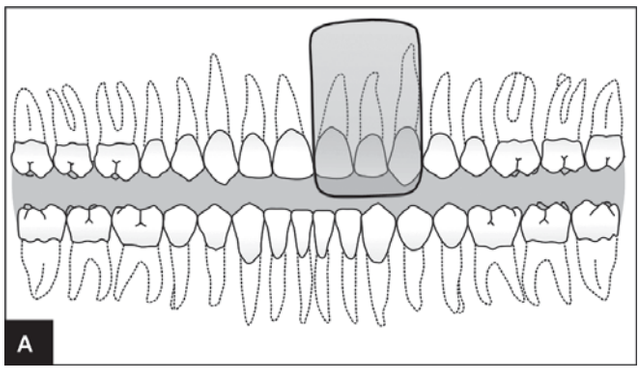


C. Projection of central ray—The point of entry is through the midline, through the tip of the nose, through the contact point of the central incisors and perpendicular to the plane bisecting the angle between the long axis of the film and the roots of the teeth (+45° to +50°)

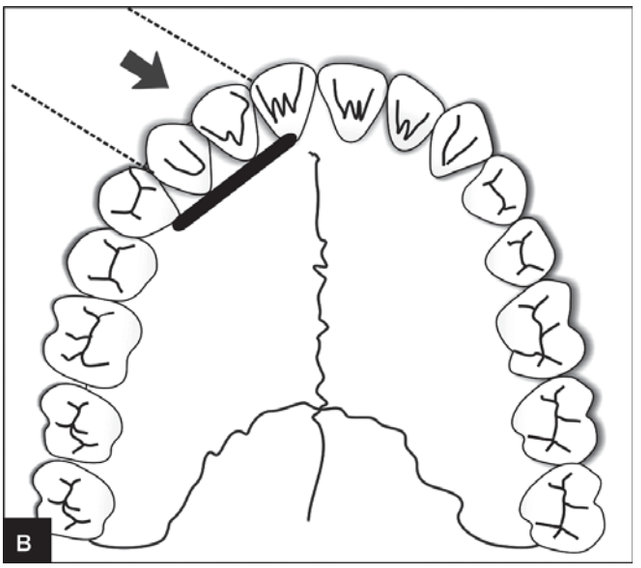


D. Radiograph of maxillary central incisors

Fig. 11.37: Short Cone Technique for Maxillary Incisors



A. Image field—Should include lateral incisor and its periapex centered on the radiograph



B. Film placement—The film is placed behind the maxillary lateral incisors. The film is placed with the superior border on the palate and the inferior border extending just beyond the incisal edges of the teeth

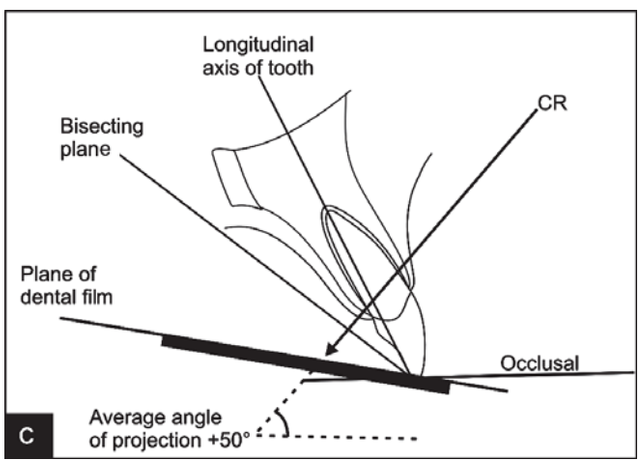
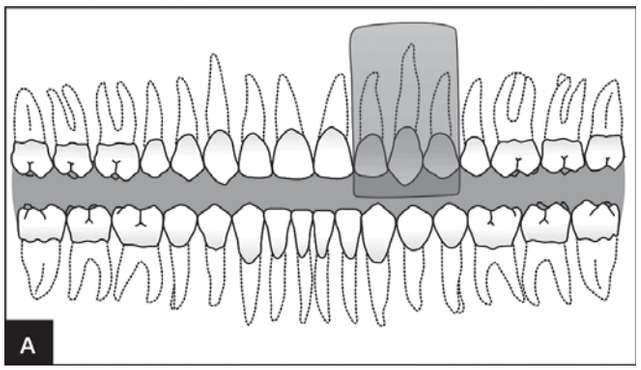


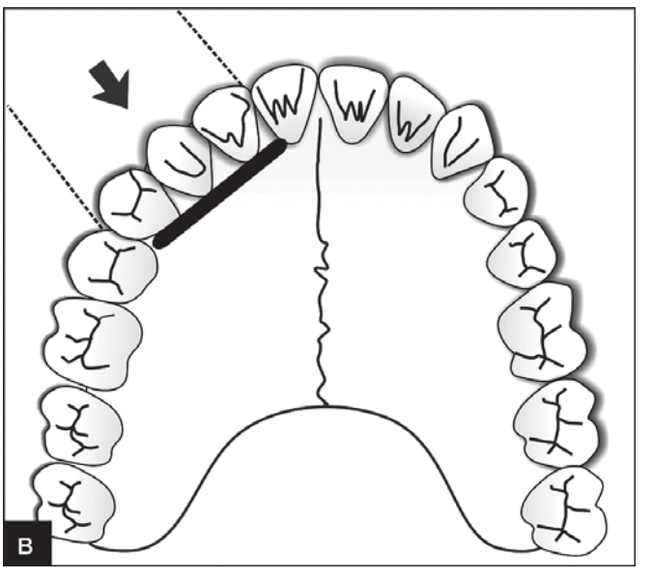
Fig. 11.38C: Projection of central ray—The point of entry is through ala of the nose about 1cm from the midline, through the middle of the lateral incisor and the open mesial contact area, and perpendicular to the plane bisecting the angle between the long axis of the film and the root of the tooth (+45° to +55°)

Fig. 11.38D: Radiograph of maxillary lateral incisors

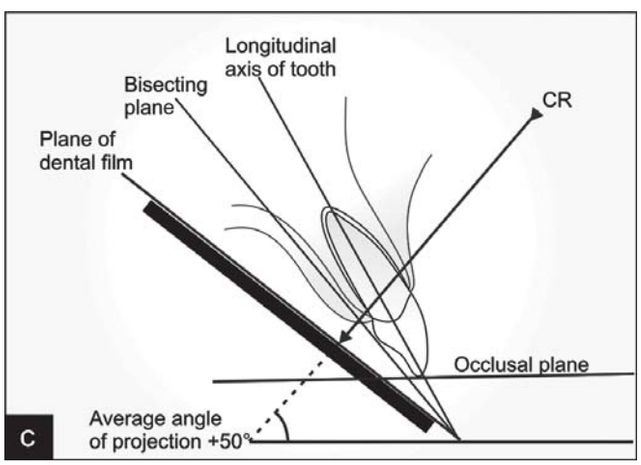
Fig. 11.38: Short Cone Technique for Maxillary Lateral Incisors



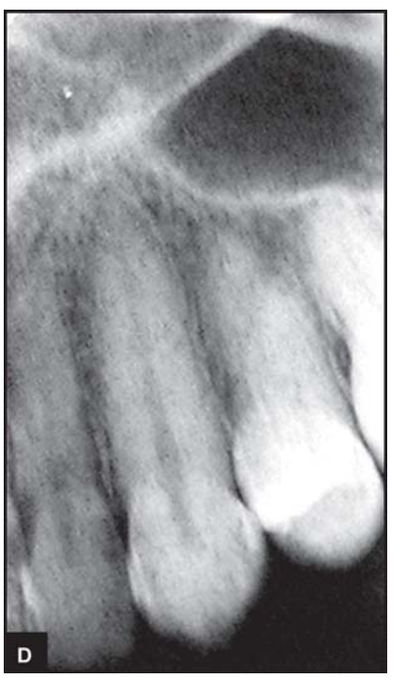
A. Image field- should include canine and its periapex centered on the radiograph



B. Film placement—The film is placed with the superior border against the palate and the inferior border extending just below the cusp of the canine, with the long axis of the tooth superimposed on the central long axis of the film

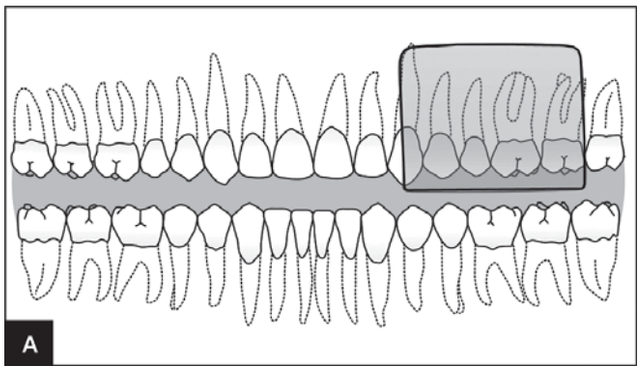


C. Projection of central ray—The point of entry is through canine eminence, and perpendicular to the plane bisecting the angle between the long axis of the film and the root of the tooth (+40 to +45°). The horizontal angulation should be through the mesial contact of the canine

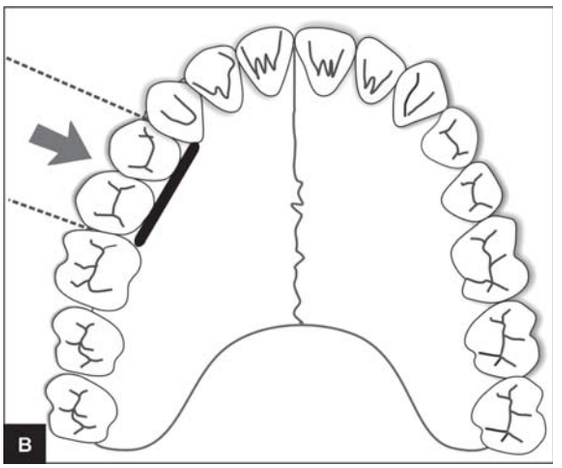


D. Radiograph of maxillary canine

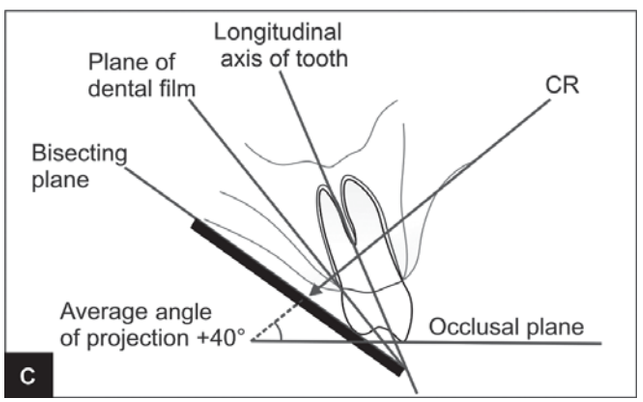
Fig. 11.39: Short Cone Technique for Maxillary Canines



A. Image field—Should include distal half of the canine, the premolars and the first molar



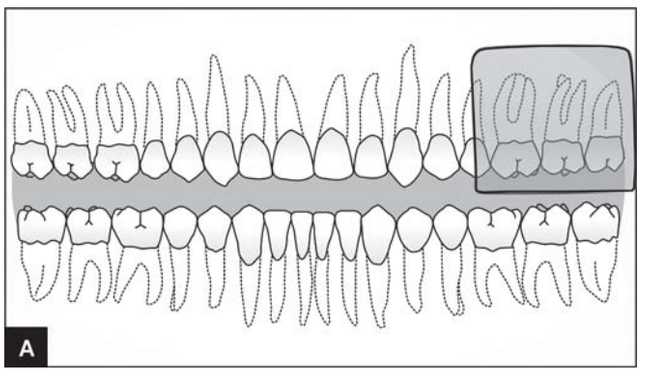
B. Film placement—The film is placed with the long dimension parallel with the occlusal plane and positioned with the superior border on the palate and the inferior border extending just below the buccal cusps of the premolars and first molar



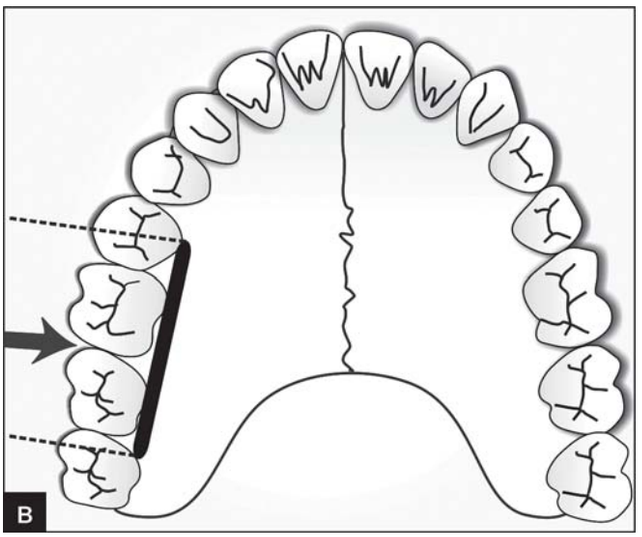
C. Projection of central ray—The point of entry is below the pupil of the eye, close to the level of the ala tragus line,and perpendicular to the plane bisecting the angle between the long axis of the film and the root of the tooth (+25° to +30°). The horizontal angulation should direct the beam between the first and second premolars

D. Radiograph of maxillary premolars

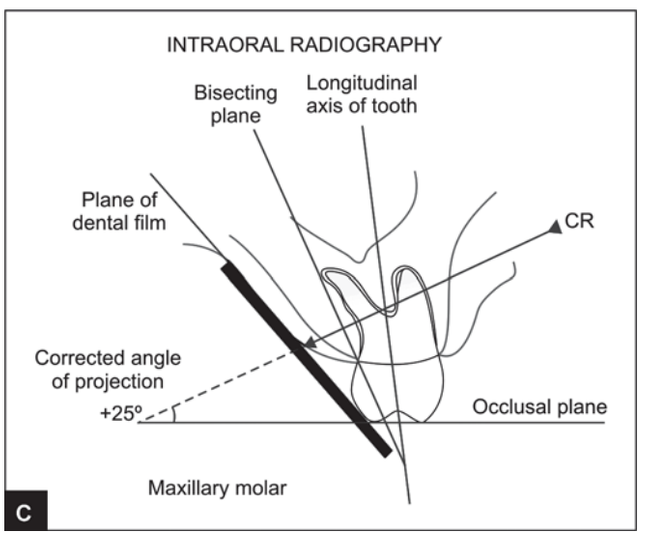
Fig. 11.40: Short Cone Technique for Maxillary Premolars



A. Image field- should include distal half of the second premolar and the three maxillary molars



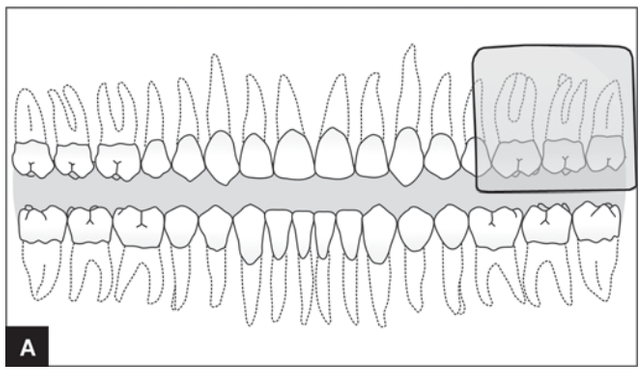
B. Film placement—The film is placed with the long dimension parallel with the occlusal plane and far enough posteriorly positioned with the superior border on the palate and the inferior border extending just below the buccal cusps of the maxillary molars



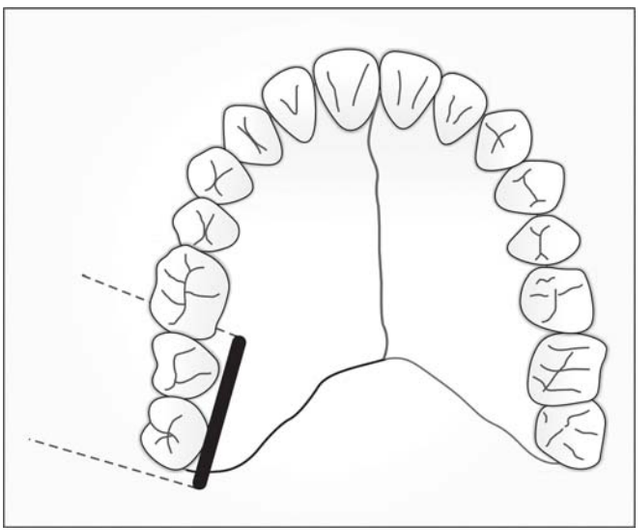
C. Projection of central ray—The point of entry is on the cheek in line with the outer canthus of the eye, below the zygoma and on an anteroposterior level with the second molar. The central ray should be perpendicular to the plane bisecting the angle between the long axis of the film and the root of the tooth (+30°). The horizontal angulation should direct the beam between the interproximal spaces between the molar teeth

D. Radiograph of maxillary molars

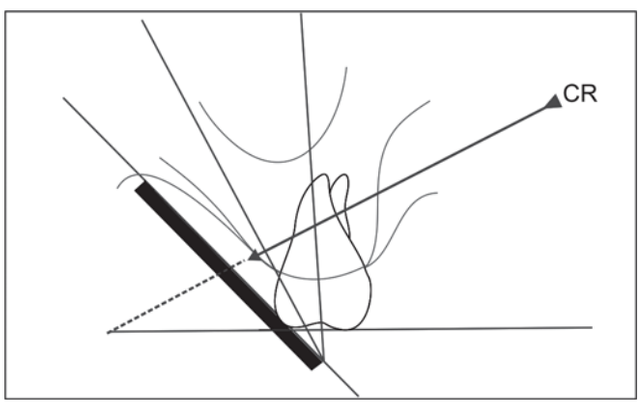
Fig. 11.41: Short Cone Technique for Maxillary Molars



A. Image field-should include the three maxillary molars



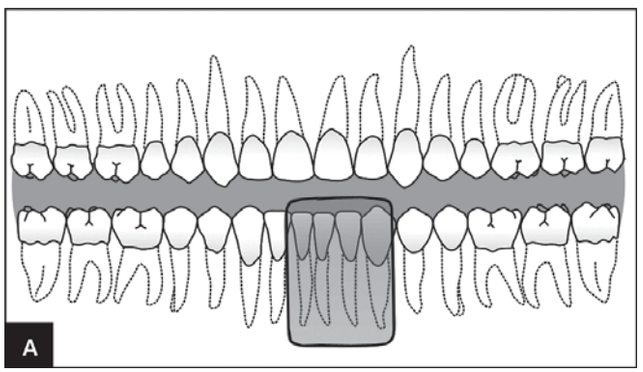
B. Film placement—The film is placed with the long dimension parallel with the occlusal plane and far enough posteriorly positioned with the superior border on the palate and the inferior border extending just below the buccal cusps of the maxillary molars



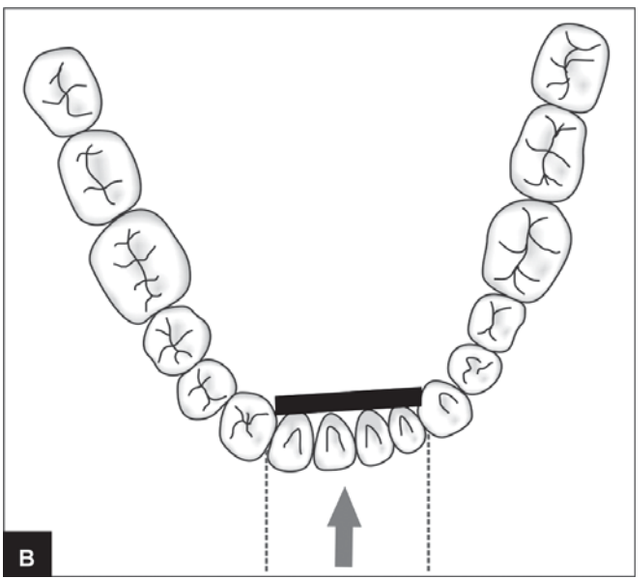
C. Projection of central ray—The point of entry is on the cheek in line with the outer canthus of the eye, below the zygoma and on an anteroposterior level between the second and third molar. The central ray should be perpendicular to the plane bisecting the angle between the long axis of the film and the root of the tooth (+25° to +30°) The horizontal angulation should direct the beam between the interproximal spaces between the molar teeth

D. Radiograph of maxillary third molar

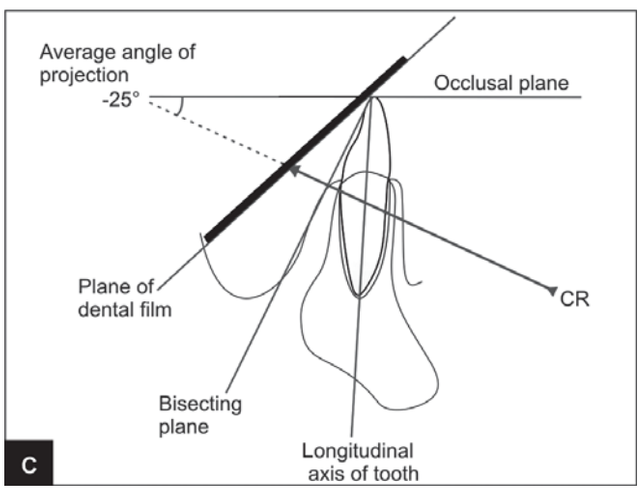
Fig. 11.41a: Short Cone Technique for Maxillary Third Molar



A. Image field—The projection should show the crowns, roots and periapical areas of the mandibular central and lateral incisors centered on the radiograph



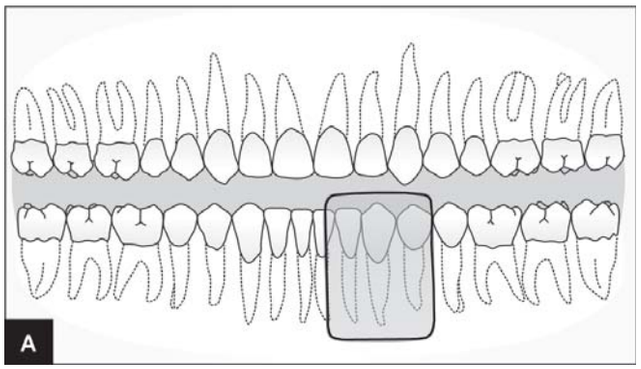
B. Film placement—The film should be placed directly behind the central and lateral incisors with the superior border on the incisal edge of the teeth and the inferior border displaced distally, extending onto the lingual mucosa



C. Projection of central ray—It should enter below the vermillion border of the lip. Approximately 1 cm from the midline. The central ray should be angled perpendicular to the bisector through the contact areas of the central and lateral incisors. The vertical angulation should be –15° to –25°

D. Radiograph of mandibular central and lateral incisors

Fig. 11.42: Short Cone Technique for Mandibular Central and Lateral Incisors



A. Image field—The projection should show the crowns, roots and periapical areas of the mandibular canine, centered on the radiograph

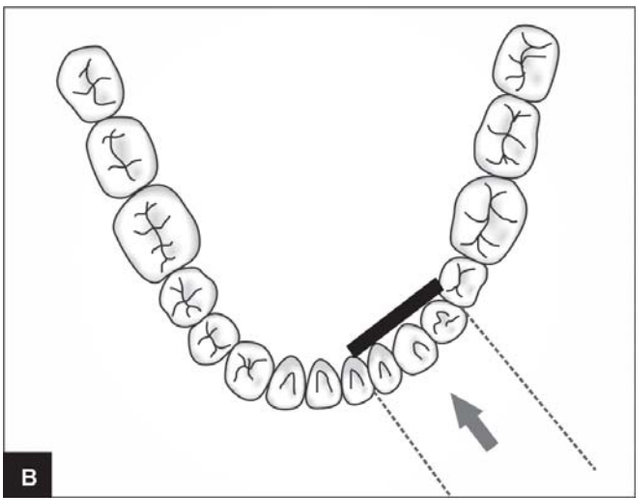
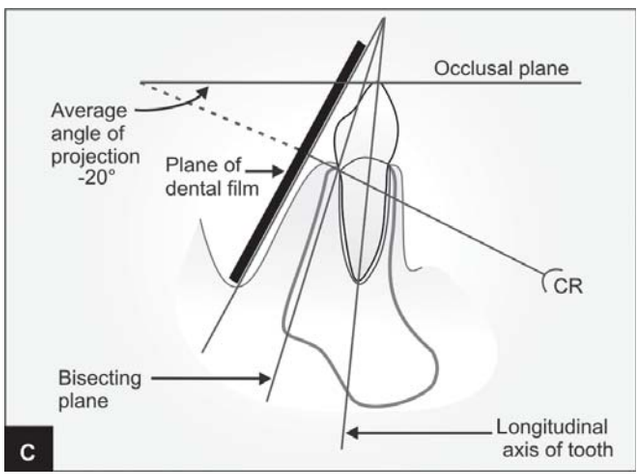


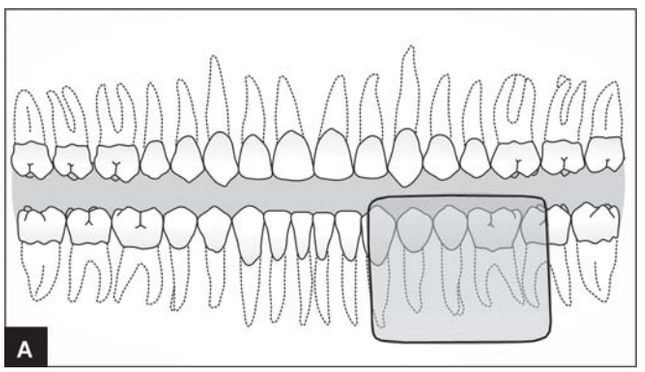
Fig. 11.43B: Film placement: The film should be placed directly behind the canine with the superior border just above the cusp of the tooth and the inferior border extending onto the lingual mucosa of the mandible



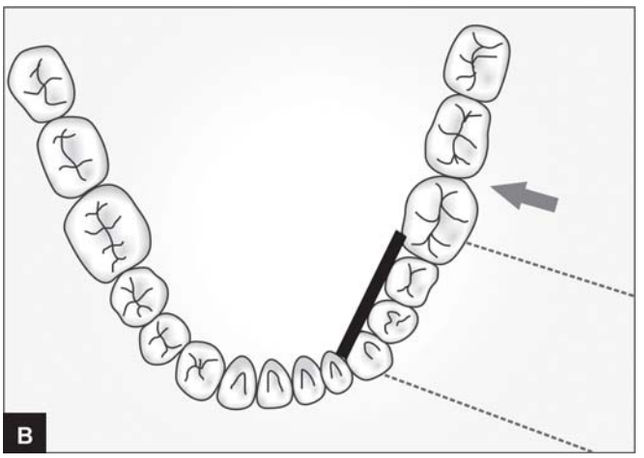
C. Projection of central ray—It should enter through the canine, approximately 3 cm from the midline. The central ray should be angled perpendicular to the bisector through the middle of the canine with a vertical angulation about –20° to –25°

D. Radiograph of mandibular canine

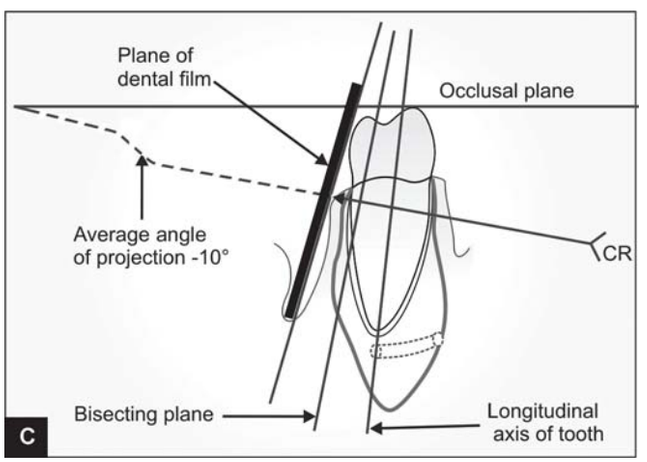
Fig. 11.43: Short Cone Technique for Mandibular Canines



A. Image field—The projection should show distal half of the canine, the premolars and the first molar



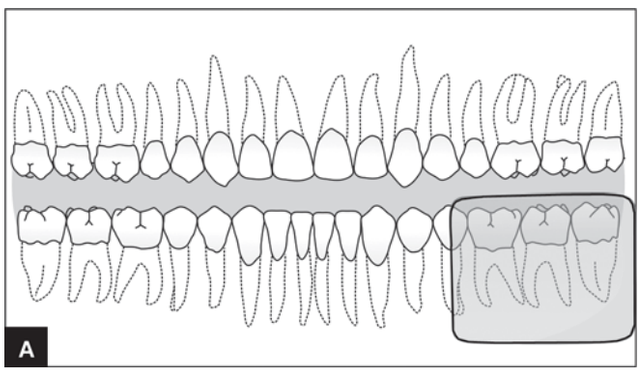
B. Film placement—The film should be placed with the inferior border positioned beneath the lateral border of the tongue and the superior border just above the cusp of the premolars. Care should be taken to extend the anterior border forward enough to cover the distal half of the canine



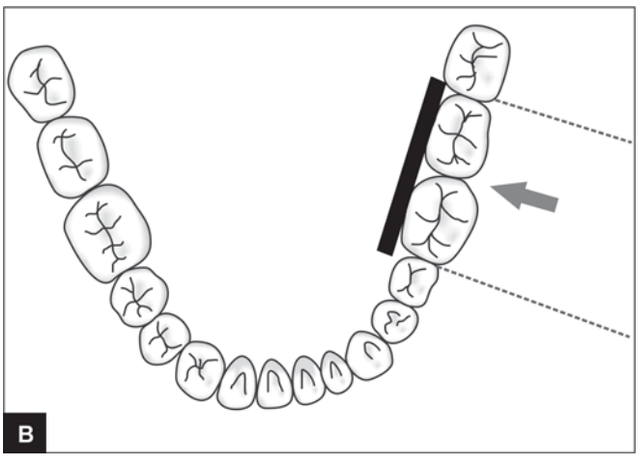
C. Projection of central ray—It should pass through the interproximal space between the first and the second premolar. The point of entry is usually below the pupil of the eye, approximately 3 cm above the inferior border of the mandible. The central ray should be angled perpendicular to the bisector through the middle of the canine with a vertical angulation about –10° to –15°

D. Radiograph of mandibular premolars

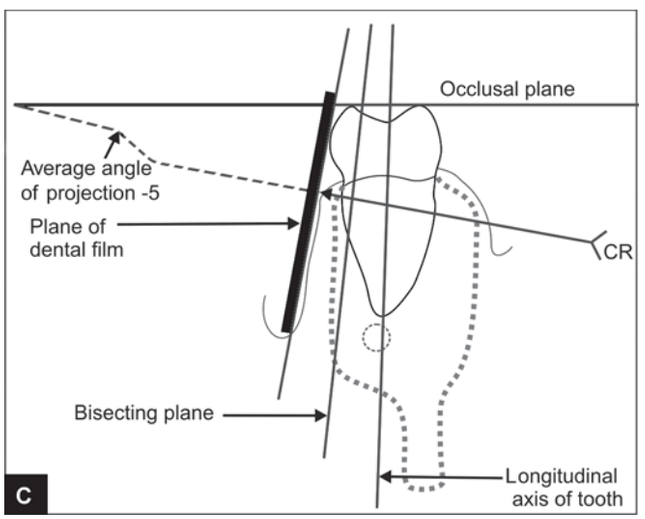
Fig. 11.44: Short Cone Technique for Mandibular Premolars



A. Image field—The projection should show distal half of the second premolar and the three mandibular molars



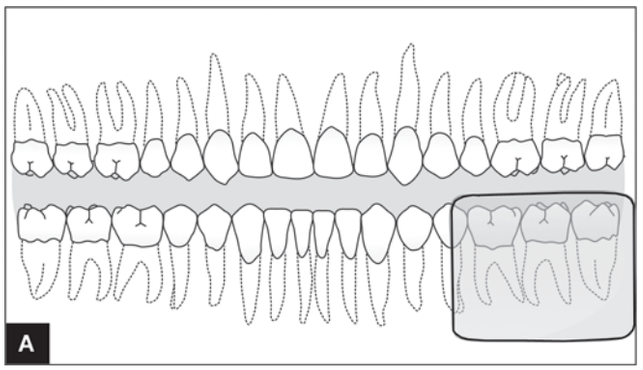
B. Film placement—The film should be placed with the inferior border positioned beneath the lateral border of the tongue and against the lingual surface of the mandible, and the superior border just above the cusps of the mandibular molars. The anterior border forward enough to cover the distal half of the second premolar



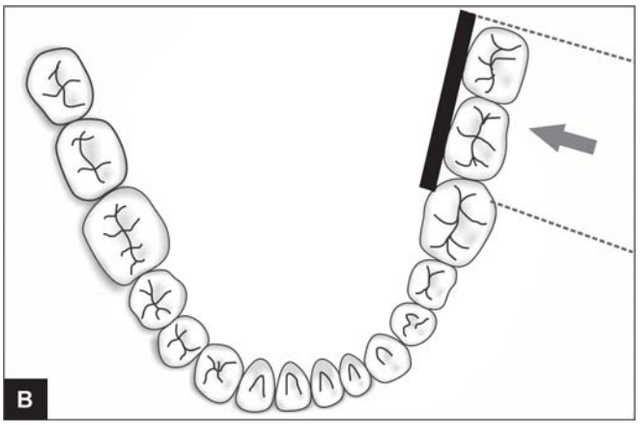
C. Projection of central ray—It should pass through the interproximal space between the molar teeth. The point of entry is on the cheek below the lateral canthus of the eye, approximately 3 cm above the inferior border of the mandible. The central ray should be angled perpendicular to the bisector through the middle of the canine with a vertical angulation about –5° to –10°.

D. Radiograph of mandibular molars

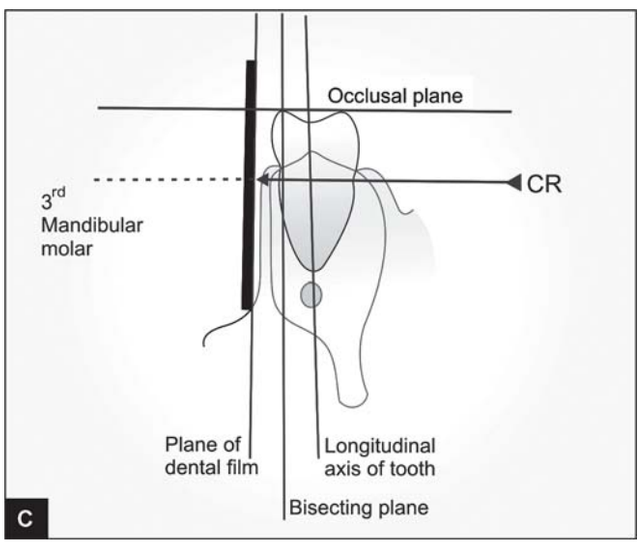
Fig. 11.45: Short Cone Technique for Mandibular Molars



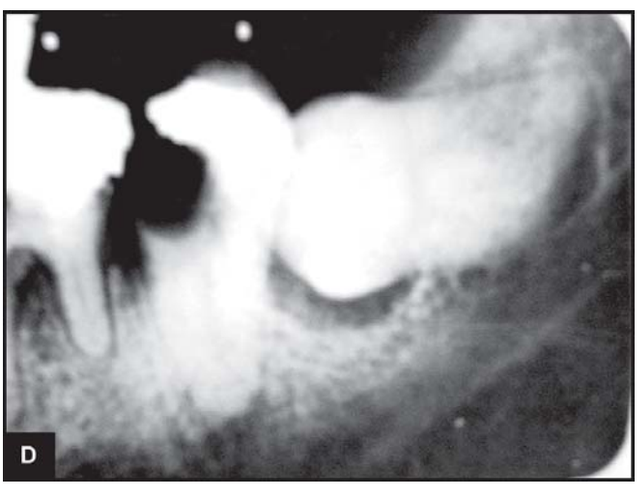
A. Image field—The projection should show the three mandibular molars



B. Film placement: The film should be placed with the inferior border positioned beneath the lateral border of the tongue and against the lingual surface of the mandible, and the superior border just above the cusps of the mandibular molars. The anterior border should cover the mesial half of the first molar



C. Projection of central ray—It should pass through the interproximal space between the molar teeth. The point of entry is on the cheek below, a little posterior to the lateral canthus of the eye, approximately 3 cm above the inferior border of the mandible. The central ray should be angled perpendicular to the bisector through the middle of the canine with a vertical angulation about –5° to –10°



D. Radiograph of mandibular third molar

Fig. 11.45a: Short Cone Technique for Mandibular Third Molar

2. Angulation problems, without the use of film holders and aiming rings, it is difficult to visualize the imaginary bisector and determine the vertical angulation. Any error in the vertical angulation will result in distortion, leading to elongation or foreshortening.
3. Incorrect horizontal angulation will result in overlapping of the crowns and roots.
4. The horizontal and vertical angles have to be assessed for every patient and considerable skill is required.
5. In the finger holding technique, the patient may shift the position of the film, before or during the exposure, leading to improper centering of the film, cone cut and /or blurring.
6. When the patient holds the film, the patient's hand is exposed to unnecessary exposure to the primary beam.
7. The periodontal bone levels are poorly represented.
8. The shadow of the zygomatic bone frequently overlies the roots of the upper molars.
9. The buccal roots of premolars and molars are foreshortened.
10. The crowns of the teeth are often distorted, thus preventing the detection of proximal caries.
11. Coning off may result if the central ray is not aimed at the center of the film.
12. It is not possible to obtain reproducible views.

Modifications in periapical technique: These may be used to accommodate variations in anatomic conditions and other practical difficulties, such as;

- Shallow palate
- Bony growths
- Mandibular premolar region
- Mandibular third molars
- Gagging
- Endodontics
- Edentulous alveolar ridges
- Children
- Handicapped patients

1. *Shallow palate*: In such cases tilting of the bite block occurs which results in a lack of parallelism between The film and the long axis of the tooth. If this does not exceed 20° the resultant radiograph is generally accepted. But, if the tilt is more than 20° then modification needs to be used (Fig. 11.46).
   - *Cotton rolls*: Two cotton rolls can be used, one placed on each side of the bite block, to position the film parallel to the long axis of the tooth, but this will result in reduced periapical coverage (Fig. 11.47).

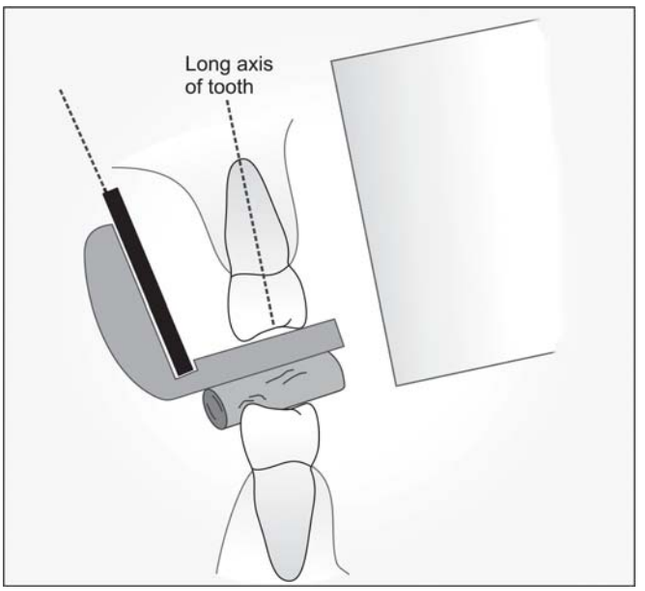


Fig. 11.46: Tilting of the bite block results in a lack of parallelism between the film and the long axis of the tooth (lack of parallelism, less than 20° is acceptable)

- *Vertical angulation*: To compensate for the lack of parallelism, the vertical angulation can be increased by 5° to 15° more than the XCP instrument indicates, but due to this , image distortion may occur.

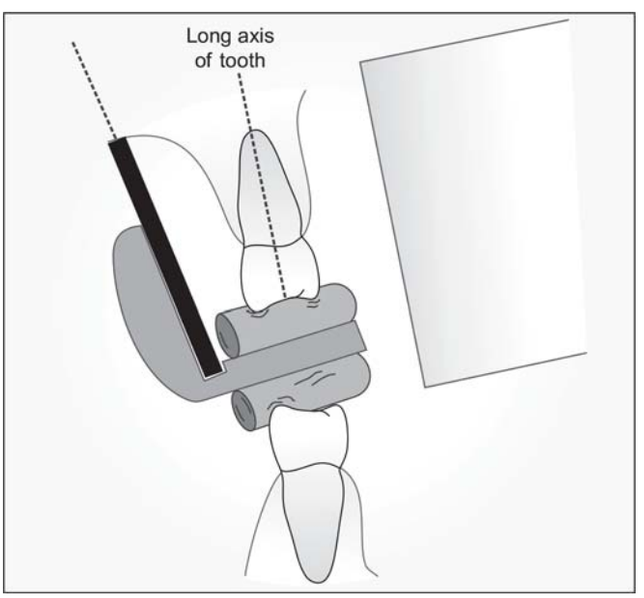


Fig. 11. 47: Two cotton rolls are used to position the film parallel to the long axis of the tooth

2. *Bony growths*: Presence of mandibular or maxillary tori, interfere with the film placement, therefore modifications are necessary.
   - *Maxillary torus*: The film must be placed on the far side of the torus (not on the torus) and then exposed (Fig. 11.48).
   - *Mandibular torus*: The film must be placed between the torus and the tongue (not on the torus) and then exposed (Fig. 11.49).
3. *Mandibular premolar region*: The floor of the mouth in this region is very sensitive and film placement causes great discomfort to the patient. Therefore certain modifications are necessary.
   - *Film placement*: The film must be placed under the tongue to avoid impinging on muscle attachments and the sensitive lingual gingiva. When inserting the film holder into the mouth, the film is tipped away from the tongue and toward the teeth being examined while the bite block is placed firmly on the mandibular premolars. When the patient closes on the bite block, the film is moved into proper position (Fig. 11.50).
   - *Film*: The lower edge of the film can be gently curved or softened, to prevent discomfort. Bending or creasing the film must be avoided.
4. Mandibular third molar; the main difficulty is the placement of the film packet sufficiently posteriorly to record the entire third mandibular molar (especially when it is horizontally impacted) and the surrounding tissues, including the inferior dental canal (Fig. 11.51). The possible solutions include:
   - Using surgical needle holder to hold and position the film packet in the mouth, as follows,
     i. Film holder is clipped securely on to the top edge of the film packet.
     ii. With the mouth open, the film packet is positioned gently in the lingual sulcus as far posteriorly as possible.

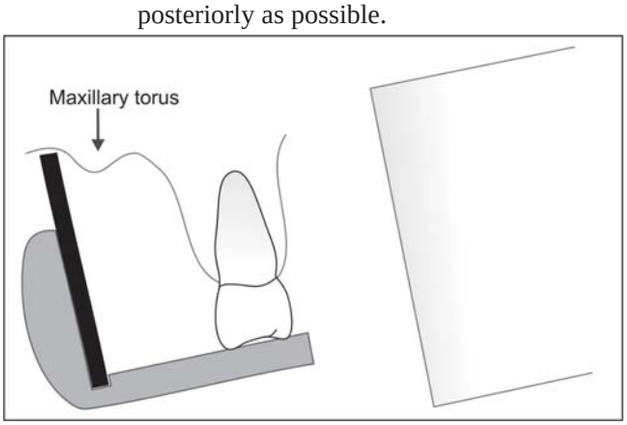


Fig. 11.48: If a maxillary torus is present, the film must be placed on the far side of the torus and then exposed

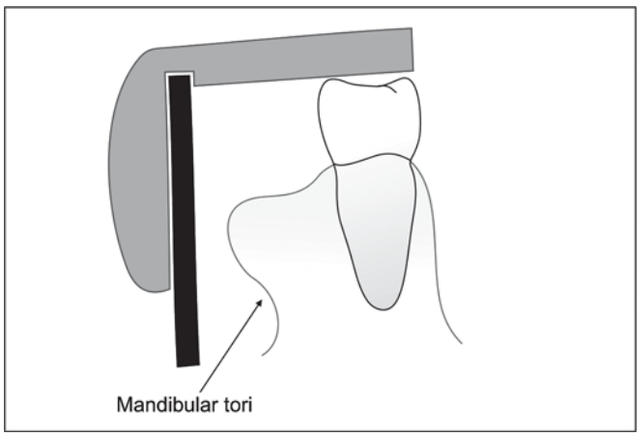
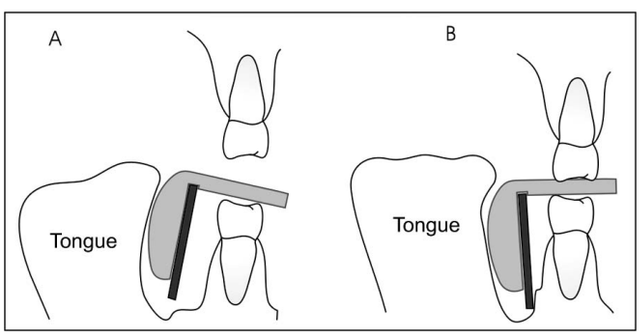


Fig. 11.49: If mandibular tori are present, the film must be placed on the far side of the tori and then exposed

     iii. The patient is asked to close the mouth on the handles of the holders (so relaxing the tissue of the floor of the mouth) and at the same time the film packet is eased further back into the mouth, if required, until its front edge is opposite the mesial surface of the mandibular first molar.
     iv. The patient is asked to support the handles of the needle holder in position
     v. The X-ray tube head is positioned at right angles to the third molar and the film packet and centered one cm up from the lower border of the mandible, on a vertical line dropped from the outer canthus of the eye (Fig. 11.52).
   - Taking two radiographs of the third molar using two different horizontal tube head angulations, as follows, (Fig. 11.53).



Figs 11. 50A and B: Positioning of the XCP instrument in the sensitive mandibular premolar area. **A.** The film is tipped away from the tongue while the bite-block is placed firmly on the mandibular premolars. **B.** When the patient closes on the bite-block, the film is moved into the proper position

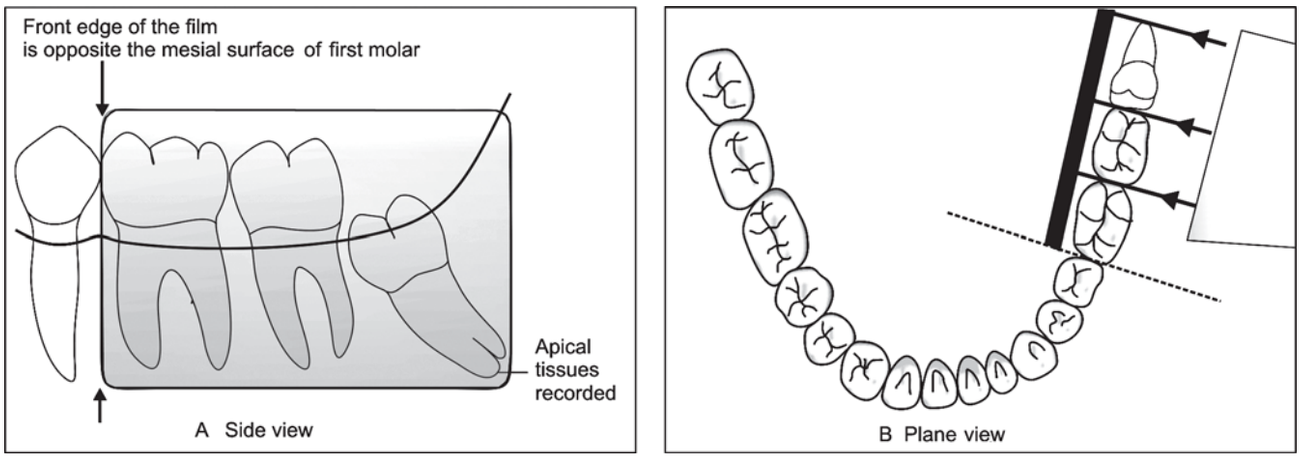


Fig. 11.51: Diagram showing ideal film packet position for mandibular third molars to ensure the tooth and apical tissues are recorded

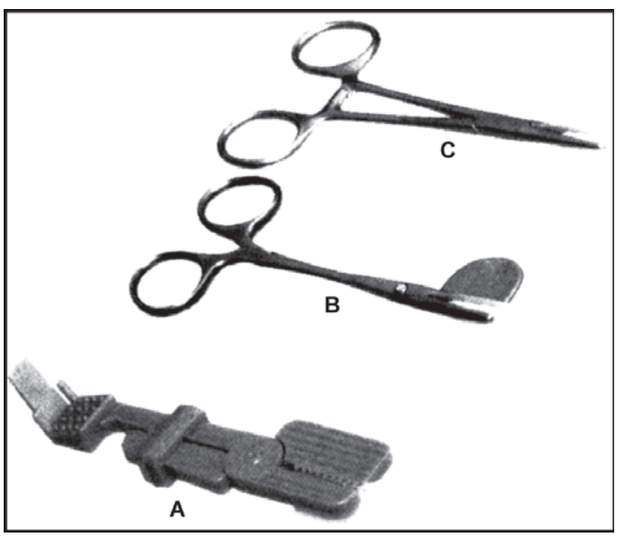


Fig. 11.52: A selection of film packet holders for mandibular third molars. **A.** Emminex or Snap-A-Ray film holder **B.** Worth film holder **C.** Conventional pair of artery forceps

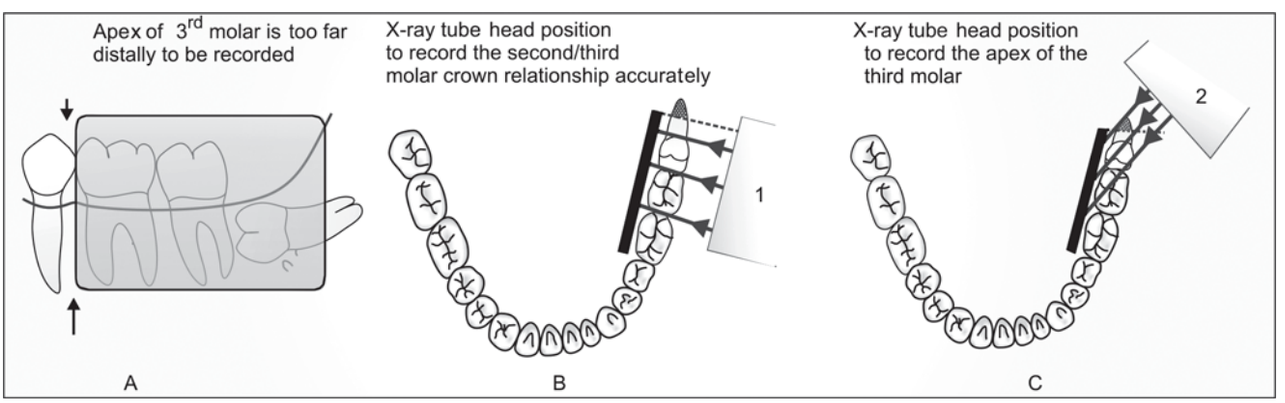


Fig. 11.53A to C: The problem of the horizontal third molar. **A.** Side view showing the often achievable film packet position. **B.** Plane view showing X-ray tube head position-1. **C.** Plane view showing X-ray tube head position-2

i. The film packet is positioned as posteriorly as possible (using the technique described with the needle holders).
ii. The X-ray tube head is aimed with the ideal horizontal angulation so the X-ray beam passes between the second and third molars. With horizontally impacted third molars, the apex may not be recorded using this positioning.
iii. A second film packet is placed in the same position as before, but the X-ray tube head is positioned further posteriorly aiming forward to project the apex of the third molar onto the film (in this position the crowns of the second and third molars become overlapped).
iv. The vertical angulation of the X-ray tube head is the same for both projections.

4. *Problems of gagging*: The gag reflex is strong in some patients. This makes the placement of the film packet in the desired position particularly difficult, especially in the upper and lower molar regions. The probable solutions are:
   - Spraying the palate with local anesthetic before attempting to position the film packet.
   - Asking the patient to concentrate on breathing deeply while the film packet is in his mouth.
   - Placing the film packet flat in the mouth (in the occlusal plane) so it does not touch the palate, and applying the principles of the bisected angle technique; the long axis of the tooth and the film packet are assessed and the X-ray tube head's position modified accordingly as shown in Figure 11.54.

5. *Endodontics*: Here the main difficulties involve;
   - Film packet placement and stabilization when endodontic instruments, rubber dam and rubber dam clamps are in position.
   - Identification and separation of root canals.
   - Assessing root canal lengths from foreshortened or elongated radiographs.

   The possible solutions are:
   - The problem of the film packet placement and stabilization can be resolved by:
     - Taping the intraoral film packet to one end of a wooden tongue spatula. This is positioned in the mouth and held in place by the patient, as shown in Figure 11.55.
     - Using the special endodontic film holders that have been developed. These incorporate a small basket in the bite platform area, to accommodate the handles of the endodontic instruments, while still allowing the film packet and the tooth to be parallel (Fig. 11.56).
   - The problem of identifying and separating the root canals can be solved by taking atleast two radiographs, using different horizontal X-ray tube head positions (Fig. 11.57).
   - The problem of assessing root length can be solved by:
     - Taking an accurate paralleling technique periapical preoperatively and measuring the lengths of the root(s) directly from the radiograph before beginning the endodontic treatment. The amount of distortion on subsequent films can then be assessed.
     - Calculating mathematically the actual length of a root canal from a distorted bisecting angle

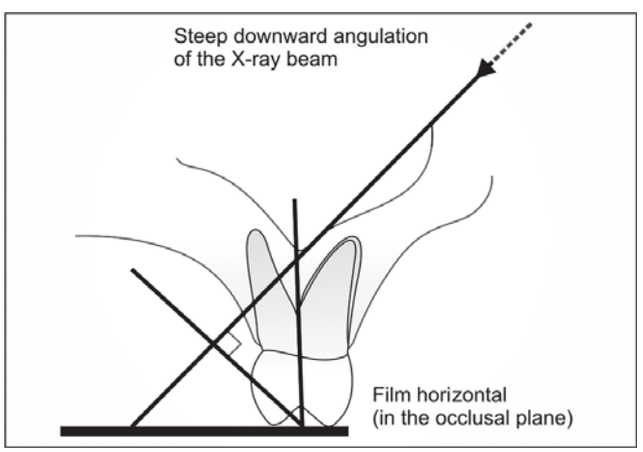


Fig. 11.54: Diagram showing the relative position of the X-ray beam to the maxillary molar, when the film is placed in the occlusal plane

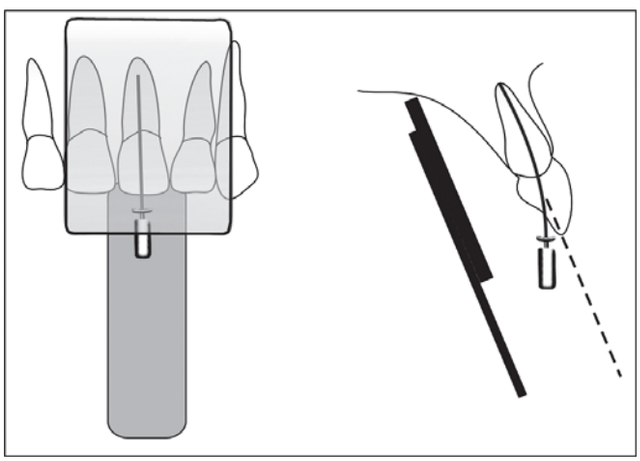
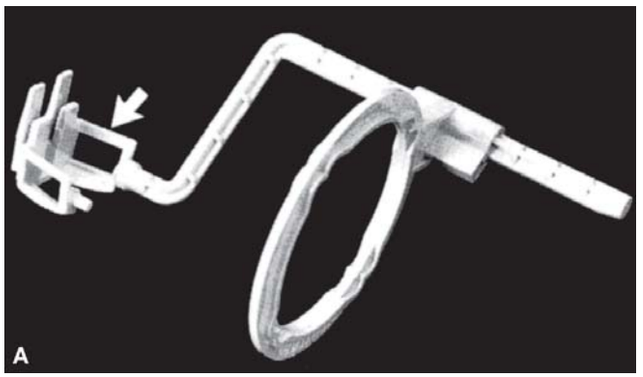
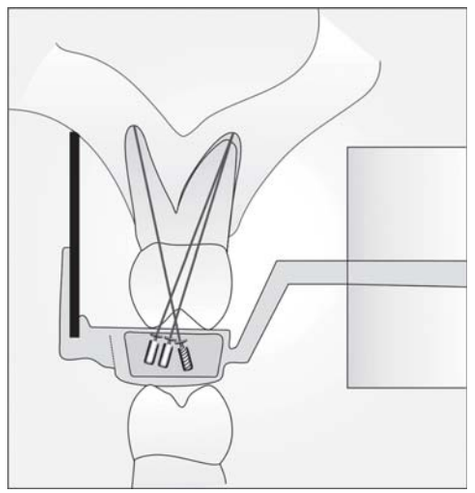


Fig. 11.55: Diagram showing the use of a wooden spatula as a film holder in endodontics





Figs 11.56A and B: A specially designed film packet holder (Endoray) for use during endodontics, incorporating a basket to accommodate the handles of the endodontic instruments and a beam aiming device. B. Diagram of the holder in place

technique periapical taken with the diagnostic instrument within the root canal at the clinically assessed apical stop.

The calculation is done as follows (Fig. 11.58).

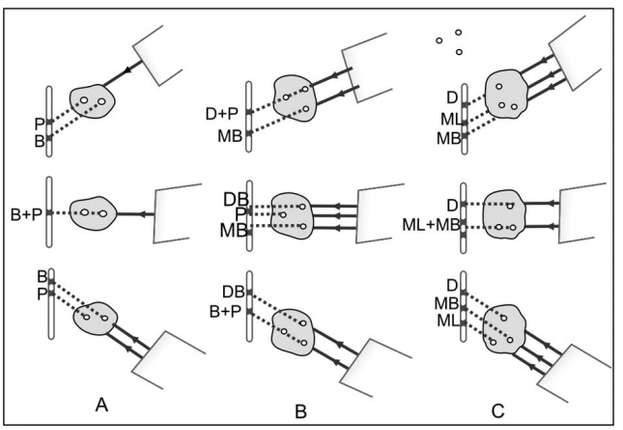
– *Measure*:
  a. The radiographic tooth length.
  b. The radiographic instrument length.
  c. The actual instrument length.

– *Substitute the measurements into the formula*:

$$\text{Actual tooth length} = \frac{\text{Radiographic tooth length} \times \text{Actual instrument length}}{\text{Radiographic instrument length}}$$

– Calculate the actual length and adjust the working length of the instrument as necessary.

6. *Edentulous ridge*: It is difficult to place the film packet. The solutions are:
   - In the edentulous patient the lack of height in the palate, or loss of lingual sulcus depth, contraindicates the paralleling technique and all periapical radiographs should be taken using a modified bisected angle technique. The long axis of the film packet and the alveolar ridge are assessed and the X-ray tube head position adjusted accordingly (Fig. 11.59).
   - In partially dentate patients, the paralleling technique can usually be used. If edentulous area causes the film packet holder to be displaced, the deficiency can be built up by using cotton rolls (Fig. 11.60).
7. *Children*: The main problem is the size of the mouth and difficulty in placing the film packet intraorally:
   - The paralleling technique is not possible in very small children, but can often be used (and is recommended)



Figs 11.57A to C: Diagram showing the different horizontal X-ray tube head positions on root separation for **A.** Maxillary premolars, **B.** Maxillary first molars, **C.** Mandibular first molars (the images of the canal are designated: P= palatal, B=buccal, MB= mesiobuccal, ML= mesiolingual and D=distal)

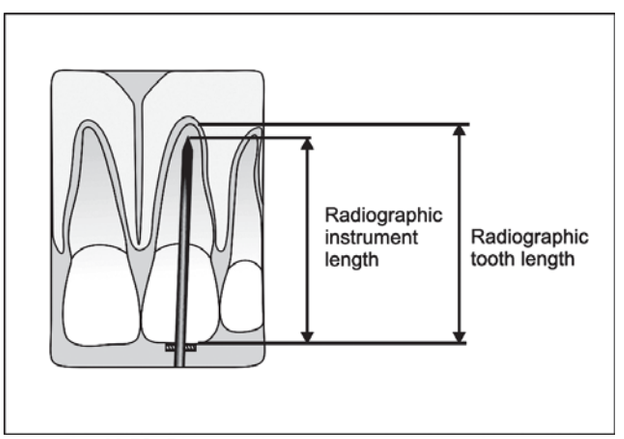
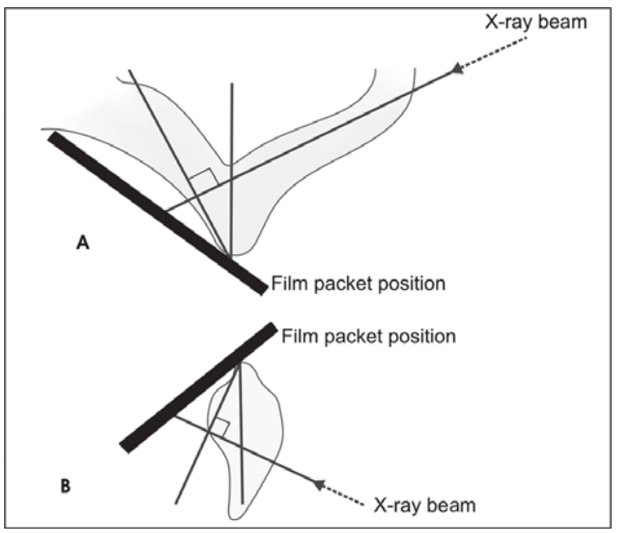


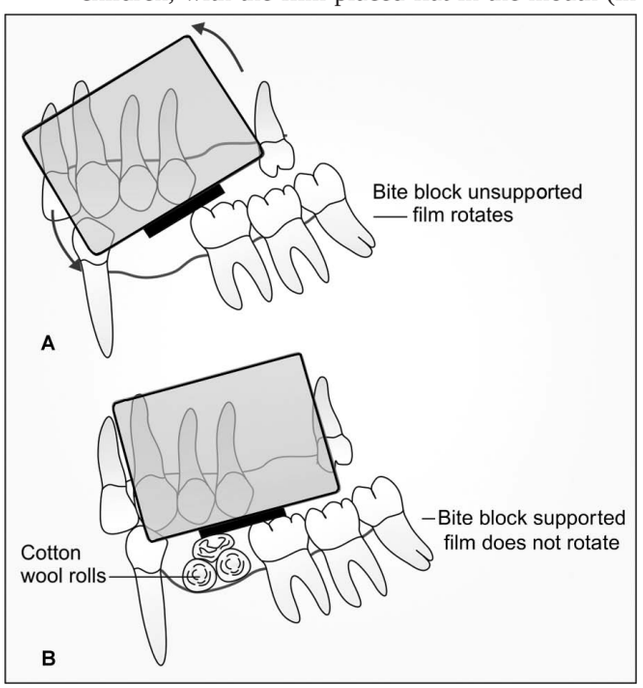
Fig. 11.58: Diagram showing the required radiographic measurements in endodontics to calculate the actual tooth length



Figs 11.59A and B: Diagram showing the relative position of the film packet and X-ray beam **A.** For the molar region of an edentulous maxillary ridge. **B.** For the molar region of an edentulous mandibular ridge

anteriorly, for investigating traumatized permanent incisors. The reproducibility afforded by this technique is invaluable for future comparative purposes.

- A modified bisected technique is possible in most children, with the film placed flat in the mouth (in the occlusal plane) and the position of the X-ray tube head adjusted accordingly (Fig. 11.61).



Figs 11.60A and B: Diagram showing **A.** The effect on the position of the film packet and holder created by an edentulous area, and **B.** How the problem can be solved using cottonwool rolls to rebuild the edentulous area, thus supporting the bite block

8. *Handicapped patients*: The main problems encountered are in obtaining the patient's cooperation and in possible anatomical difficulties in relation to film packet placement, the possible options are:
   - Only attempting radiographic investigations appropriate to the limitations imposed by the patient's handicap.
   - Using the paralleling technique, if possible, for periapical radiography because, as mentioned earlier, with this technique the relative positions of the film packet, teeth and X-ray beam are maintained, irrespective of the position of the patient's head.

Summary of Comparison between Short Cone and Long Cone Techniques

Short cone	*Long cone*
1. Diffusion and distortion of the image	1. Sharp details of the image obtained
2. Increased chances of elongation or shortening of the image	2. Image obtained is of the same size and shape as the object.
3. Distorted image of the teeth due to oblique exposure and bending of the film	3. Image of the teeth nearly anatomically accurate, from use of right angle exposure and flat surface of the film
4. Shadows of the alveolar bone tend to fill the interproximal spaces	4. Alveolar crest seen in true relationship to the teeth
5. More vertical angulation	5. Less vertical angulation, thus similar buccal and lingual parts of the teeth appear close to each other in the radiograph, and more tooth area under neath restorations is revealed. (Fig. 11.62)
6. Superimpositon of the shadow of the zygomatic arch on the teeth (Fig. 11.63)	6. Less vertical angulation in the maxillary molar region avoids the shadow of the zygomatic arch and the teeth apices and maxillary sinus are better seen
7. Easier technique to maneuver and requires less space	7. Needs a larger working space
8. More effective when the palate is shallow, children with adult size teeth but underdeveloped jaws (Fig. 11.64)	8. In a similar situation apices of the teeth may be cut off
9. In rare cases when the teeth are longer than film, the entire tooth may be seen, by over angulating the vertical angulation	9. This is not possible in the long cone technique
10. Cone cutting is a common error especially, in the maxillary third molar area (Fig. 11.65)	10. The PID, helps reduce such errors
11. Curved film due to incorrect finger pressure (Fig. 11.66)	11. Use of film holding device prevents such an error

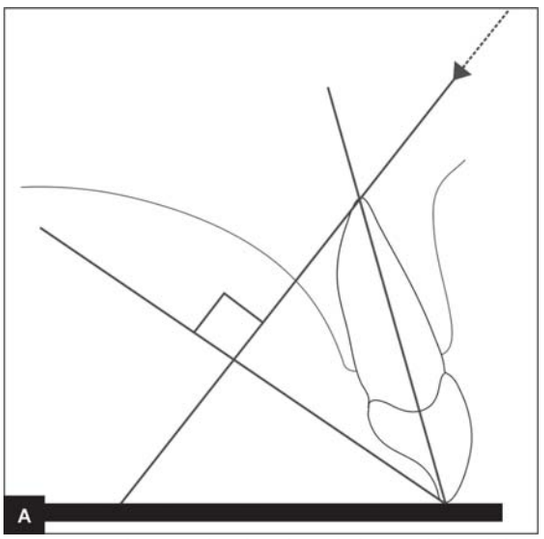


Fig. 11.61A: Diagram showing the relative position of the film packet, in the occlusal plane, and the X-ray beam

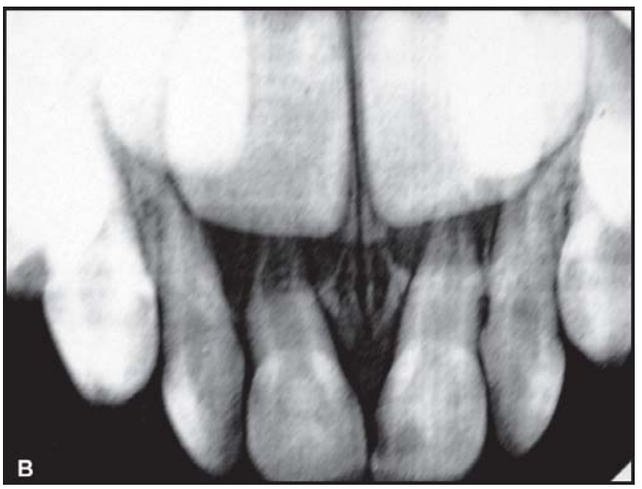


Fig. 11.61B: Resultant radiograph

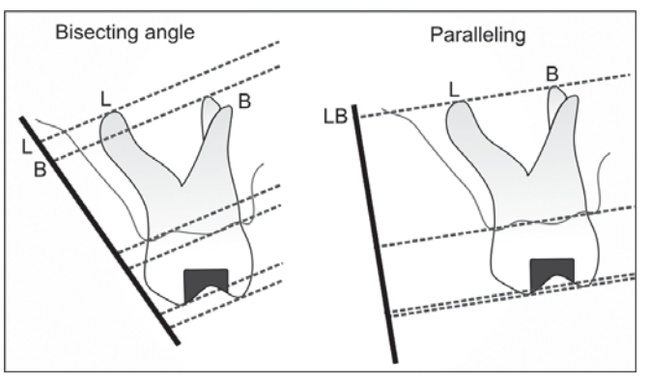


Fig. 11.62: Diagram showing vertical angulations of bisecting angle and paralleling techniques placing buccal and lingual tooth parts at different levels of the radiograph. Less vertical angulation shows more of the area underneath the dental restorations (Z)

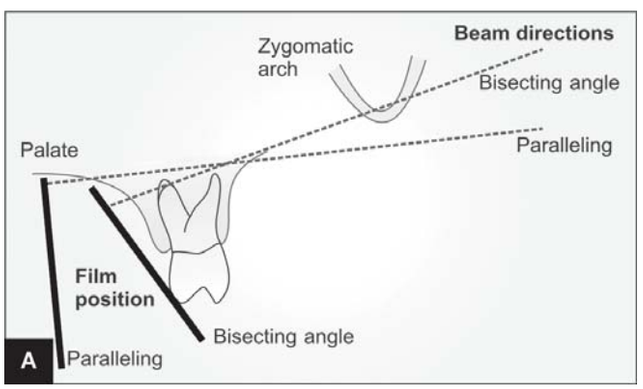


Fig. 11.63A: Vertical X-ray beam directions and film positions in bisecting angle and paralleling techniques for maxillary molar region

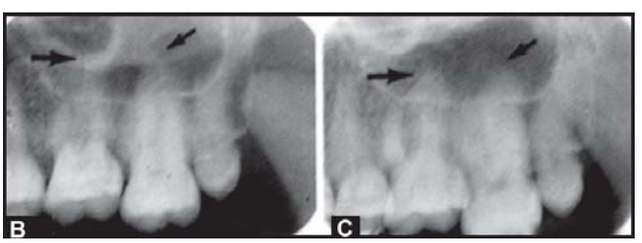


Fig. 11.63B: Radiographs made with **B.** Bissecting angle technique **C.** Parallelling technique

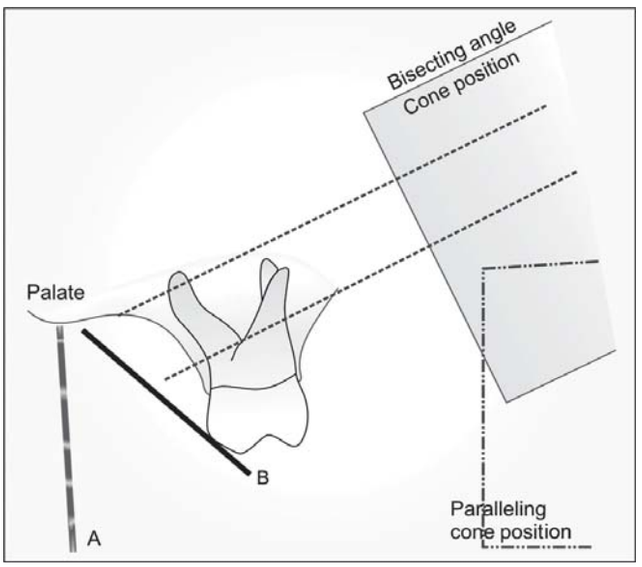


Fig. 11.64A: Shallow palate vault. Film in paralleling position **A.** Cannot achieve sufficient height, Bisecting angle technique **B.** Can provide satisfactory radiographic image

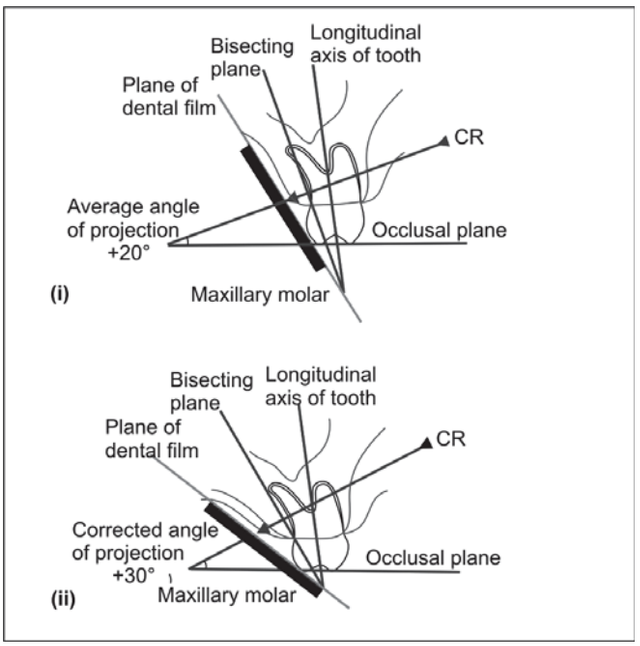
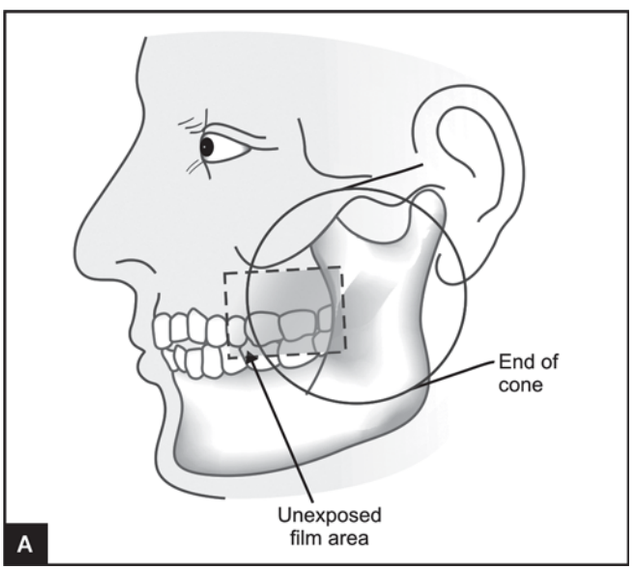
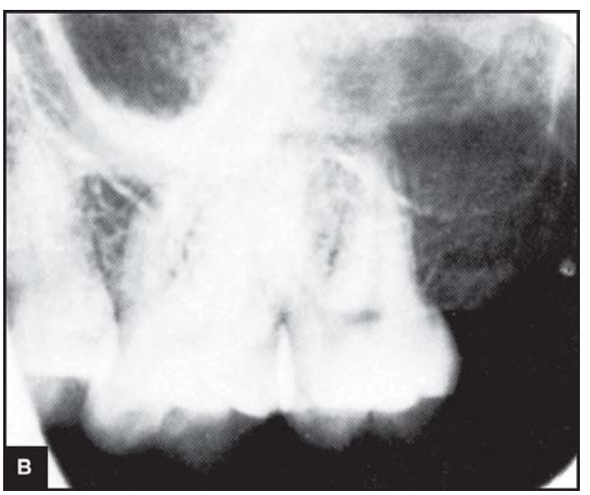


Fig. 11.64B: i. A high vault requires approximately + 20° angulation in the upper molar region. **ii.** A low vault requires approximately +30° angulation in the upper molar region





Figs 11.65A and B: Cone cutting of the mesial portion of the maxillary molar radiograph due to improper placement of film

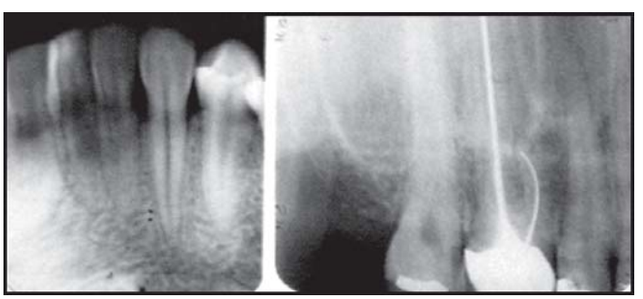


Fig. 11.66: Streaked and distorted images caused by curved films

BITE WING RADIOGRAPHY

The Bite Wing Technique or the Interproximal Technique is a method used to examine the interproximal surfaces of teeth.

Indications

1. Detection of interproximal caries.
2. Monitoring progression of dental caries.
3. Detection of secondary caries below restorations.
4. Evaluating periodontal conditions.
5. Useful for evaluating alveolar bone crest and changes in bone height can be assessed by comparison with the adjacent teeth.
6. For detecting calculus deposited in the interproximal areas (for better visualization, exposure should be reduced as calculus has relatively low density).

Principles

- The film is placed in the mouth parallel to the crowns of both the upper and lower teeth.
- The film is stabilized when the patient bites on the bite wing tab of bite wing film holder.
- The central ray of the X-ray beam is directed through the contacts of the teeth, using a +10° vertical angulation (Fig. 11.67).

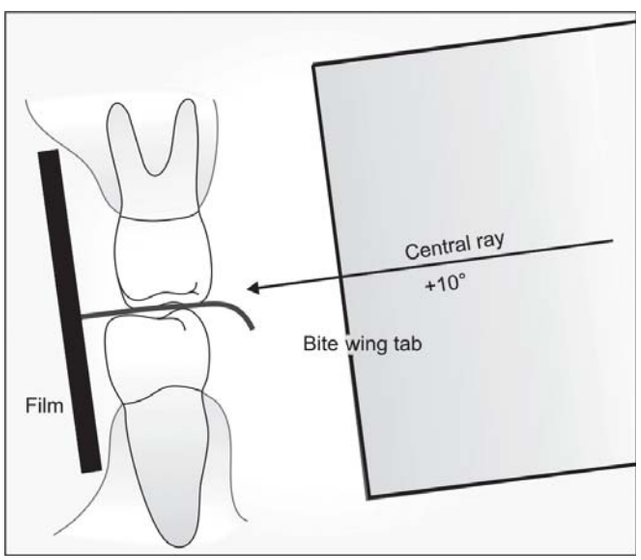


Fig. 11.67: Position of the film, bite wing tab and the central ray in the bite wing technique. The film is parallel to the crown of the upper end lower teeth. The central ray is directed downwards (+10° vertical angulation)

Film Holder and Bite Wing Tab

A film holder as already defined is used to stabilize the film. Those used for bite wing radiography are:

- Rinn XCP bite wing instruments: Which have a plastic bite blocks, plastic aiming rings and metal indicator arms. A snap ring collimator may be added to reduce the exposure to the patient. These holders are reusable.
- *Bite wing tab*: is an alternative to a film holding device. A film can be fitted with a bite tab or bite loop. This is a heavy paper board tab or loop with adhesive which may be attached to the white side (tube side) of the periapical film. Readymade bite wing films with attached tabs are also available.

Films

Four sizes of bite wing films are available.

- Size 0: used to study posterior teeth of children, always placed horizontally.
- Size 1: used to examine posterior teeth in mixed dentitions or anterior teeth of adults. It is placed horizontally for the former and vertically for the latter.
- Size 2 : used to examine posterior teeth of adults and is always kept horizontally.
- Size 3 : is a longer and narrower film used only for bite wing radiographs and spans horizontally the premolar to molar region. But it is not recommended as the difference in the curvature of the dental arch between the premolar and molar areas results in overlapping of the contacts.

Position Indicating Device and Angulations

If the bite wing holder is used, the aiming ring dictates the proper PID angulations, but if the bite wing tab is used, then both the horizontal and vertical angulations must be precisely determined.

Horizontal angulations: The central ray is directed perpendicular to the curvature of the arch and through the contact areas of the teeth.

Vertical angulations: A +10° vertical angulation is recommended for the bite wing radiograph, to compensate for the slight bend of the upper portion of the film and the slight tilt of the maxillary teeth (Fig. 11.68).

Patient Positioning

1. Briefly explain the procedure.
2. Patient is seated upright and the chair adjusted to a comfortable working position.

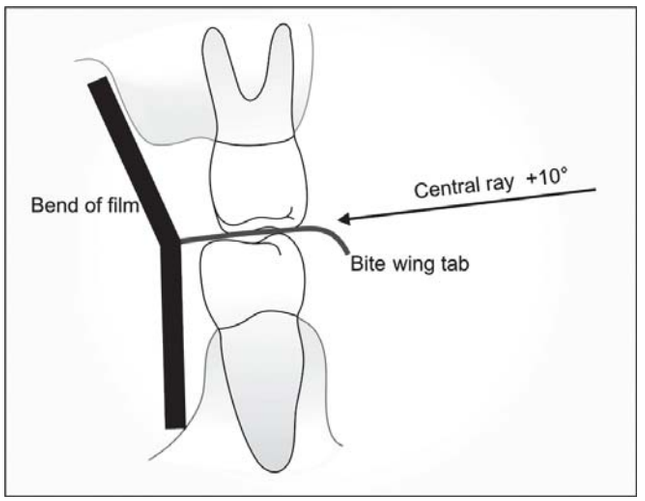


Fig. 11.68: A +10° vertical angulation is used to compensate for the slight bend of the upper portion of the film and the tilt of the maxillary teeth

3. Adjust the head rest to support and position the patient's head so that the upper arch is parallel to the floor and the mid sagittal (middle) plane is perpendicular to the floor.
4. Secure the lead apron and thyroid collar.
5. Remove all foreign objects from the face and mouth.

Five Basic Rules to follow in the Bite Wing Technique

1. *Film placement*: The film must be placed to cover the prescribed area.
2. *Film position*: The film must be positioned parallel to the crowns of both the upper and lower teeth and stabilized by biting on the film holder or tab.
3. *Vertical angulation*: The central ray must be directed at +10°.
4. *Horizontal angulation*: The central ray must be directed through the contact areas between the teeth.
5. *Film exposure*: The X-ray beam must be centered on the film to ensure that all the areas of the film are exposed and thus partial image or cone cut is avoided.

The specific positioning for different areas of the mouth for bite wing technique are shown in the Figures 11.69 to 11.70.

Modifications in Technique

May be used in cases where,

- *Edentulous spaces*: A cotton roll should be placed in the area of the missing tooth or teeth, to support the bite wing tab or film holder. When the patient closes the mouth, the opposing teeth occlude on the cotton roll and support the bite wing holder or tab. Failure to support the tab or holder will result in a tipped occlusal plane.
- *Bony out growths*: Especially a mandibilar tori, may cause problems with film placement. The film must be placed between the tori and the tongue, not on the tori.

In case the tori is large and the film is placed far from the teeth the patient may not be able to bite on the bite tab, in such cases bite wing holders are recommended.

Advantages (with using holders)

1. Simple.
2. Film packet held firmly in position and cannot be displaced by the tongue.
3. Position of the X-ray tube-head is determined by the holder, thus it is less operator dependent, ensuring that the X-ray beam is always at right angles to the film packet.
4. Avoids coning off of the anterior part of the film.
5. Holders are autoclavable or disposable.

Disadvantages (with using holders)

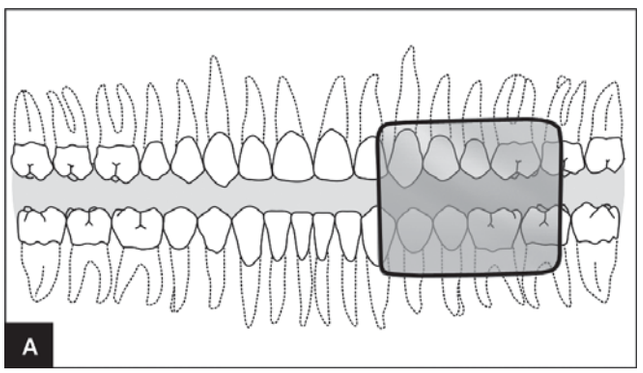
1. Position of the holder in the mouth is operator-dependent and not accurately reproducible, thus not suitable for monitoring progression of caries.
2. Positioning of the holder can be uncomfortable for the patient.
3. Some holders are relatively expensive.
4. Holders are usually not suitable for children.

Advantages (with using bite tab)

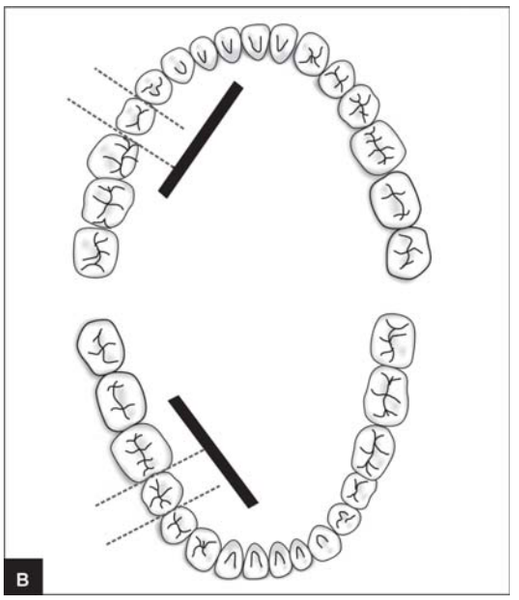
1. Simple.
2. Inexpensive.
3. The tabs are disposable, so no extra cross infection control procedures required.
4. Can be used easily in children.

Disadvantages (with using bite tab)

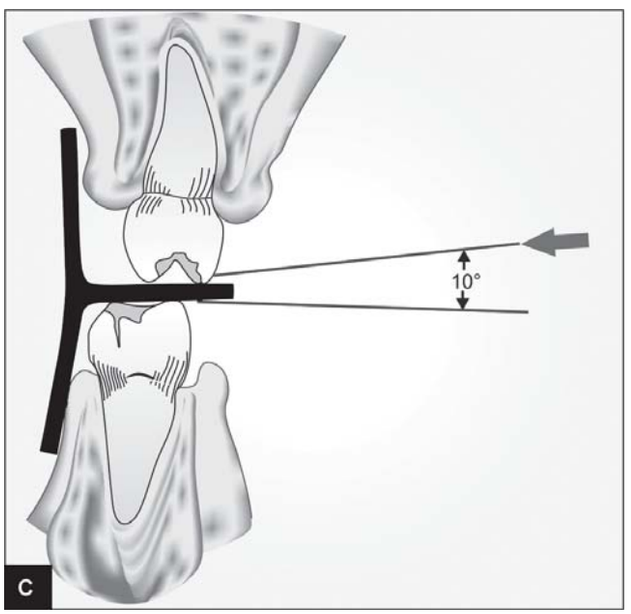
1. Arbitary, operator-dependent assessment of horizontal and vertical angulations of the X-ray tube-head.
2. Radiographs are not accurately reproducible, so not suitable for monitoring the progression of caries.
3. Coning off of the anterior part of the film is common.
4. The tongue can easily displace the film packet.



A. Image field – should show the distal portion of the mandibular canine anteriorly and show equally the crowns of the maxillary and mandibular premolars



B. Film placement—Place the film between the tongue and teeth, as far from the lingual surface of the teeth to prevent interference by the palate on closing and parallel to the long axis of the teeth as possible. The anterior border of the film should extend beyond the contact area between the mandibular canine and the lateral incisor



C. Projection of central ray—Identify the point of entry by retracting the cheek and determining that the central ray should enter the line of occlusion at the point of contact between the second premolar and first molar. A vertical angulation of +10° is recommended

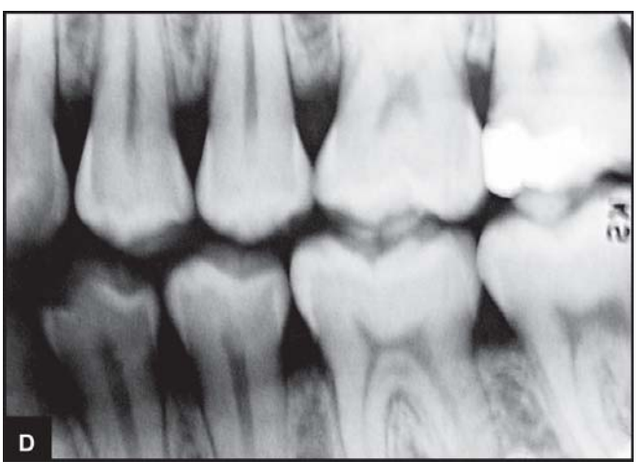
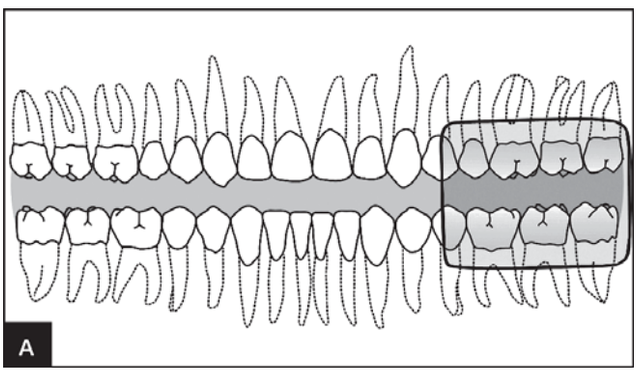
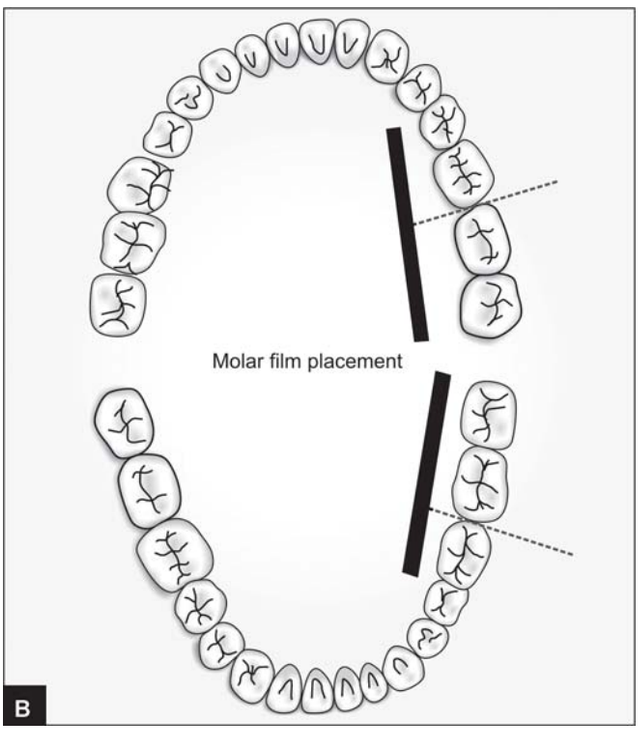


Fig. 11.69: Radiograph of premolar bite wing projection

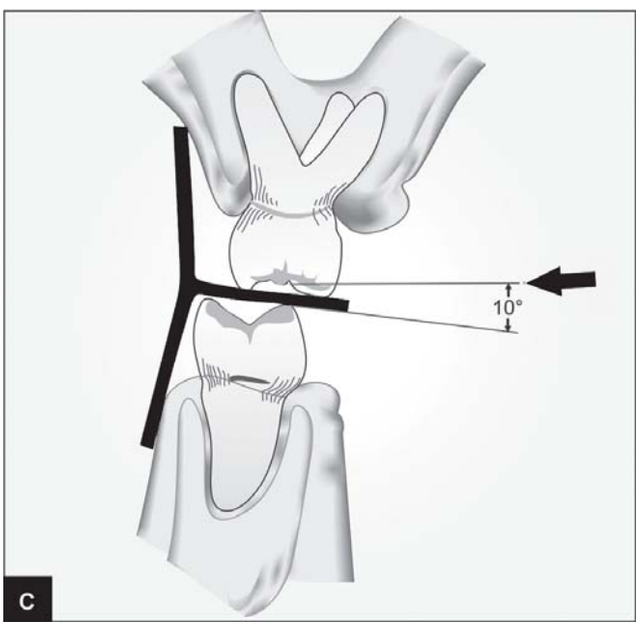
Fig. 11.69: Premolar Bite Wing Projection



A. Image field – Should show the distal surface of the most posterior erupted molar and equally the crowns of the maxillary and mandibular molars



B. Film placement—Place the film between the tongue and teeth, as far lingual as possible to avoid contacting the sensitive attached gingiva. The distal margin of the film should extend 1 to 2 mm beyond the most posterior erupted molar



C. Projection of central ray—The central ray should enter the cheek below the lateral canthus of the eye at the level of the occlusal plane, through the contact of the first and second molars. A vertical angulation of +10° is recommended

D. Radiograph of molar bite wing projection

Fig. 11.70: Molar Bite Wing Projection

Reproducible Film Packet Holder

A recent advance in bite wing technique has been the development of a holder incorporating two localization scales (Fig. 11.71). These allow the position of the holder relative to the teeth on both sides of the arch to be recorded, ensuring a reproducible position for subsequent radiographs.

Advantages

1. Film packet is held firmly and cannot be displaced by the tongue.
2. Position of the holder relative to the teeth is recordable and reproducible.
3. Position of the X-ray tube head determined by the holder ensuring that the X-ray beam is always at right angles to the film packet.
4. Avoids coning off of the anterior part of the film.
5. All parts of the holder are autoclavable.

Disadvantages

1. Positioning of the holder can be uncomfortable for the patient.
2. To be able to use localization scale on both sides of the arch, the film may have to be placed some distance from the teeth towards the midline. This can increase the discomfort for the patient.
3. Positioning the film holders and recording this position can be awkward for the inexperienced operator.
4. Holders are not suitable for children or for adult vertical bite wings.
5. Holders are relatively expensive.

OCCLUSAL RADIOGRAPHY

This technique is used to examine large areas of the upper and lower jaw. The palate and floor of the mouth may also be examined.

This is a supplementary radiographic technique that is usually used in conjunction with periapical or bite wing radiographs.

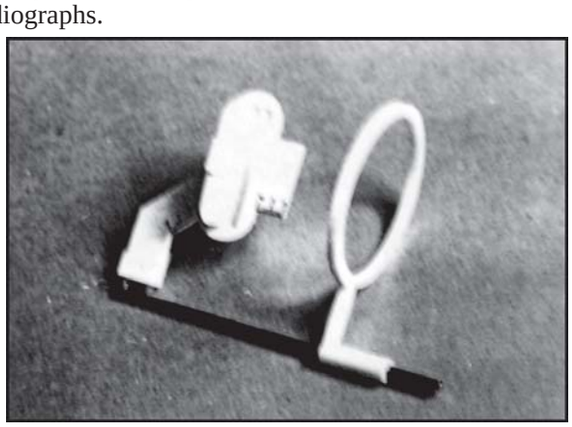


Fig. 11.71: The Benn reproducible bite wing film packet holder

Indications

- To locate retained roots of extracted teeth.
- To locate supernumerary, unerupted or impacted teeth (especially impacted canine and third molars).
- To locate foreign bodies in the maxilla or mandible.
- To locate salivary stones in the duct of the submandibular gland.
- To locate and evaluate the extent of lesions, (e.g. cysts, tumors, malignancies) in the maxilla or mandible. It is especially indicated to determine the mesial and lateral extent of the lesion and it's extent on the palate.
- To evaluate boundaries of the maxillary sinus (anterior, mesial and lateral outline).
- To evaluate fractures of the maxilla and mandible. (location, extent and displacement).
- To aid in the examination of patient's who cannot open their mouths more than a few millimeters. Or in adults and children who are unable to tolerate periapical films.
- To examine area of cleft palate.
- To measure changes in the size and shape of the maxilla and mandible.
- As a midline view, when using the parallex method for determining the bucco/palatal position of unerrupted canines.

Classification of Occlusal Views

I. Maxillary
   1. Cross-sectional
   2. Topographic
      i. Anterior
      ii. Posterior/lateral
   3. Pediatric

II. Mandibular
   1. Cross-sectional
   2. Topographic
      i. Anterior
      ii. Posterior/lateral
   3. Pediatric

Basic Principle

1. Film is positioned with the white side facing the arch that is being exposed.
2. Film is placed in the mouth between the occlusal surfaces of the maxillary and mandibular teeth.
3. The film is stabilized when the patient gently bites on the surface of the film.
4. For maxillary occlusal films the patient's head must be positioned so that the upper arch is parallel to the floor and the midsagittal plane is perpendicular to the floor.
5. For mandibular occlusal films the patient's head must be reclined and positioned so that the occlusal plane is perpendicular to the floor.

Film

Special occlusal films are marketed which are bigger than the intraoral films.

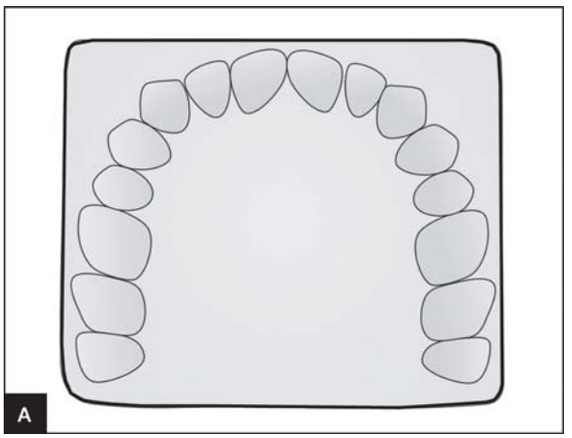
Maxillary Cross-sectional View (Fig. 11.72)

Image field: This projection shows the palate, the zygomatic process of the maxilla, the anterior-inferior aspects of each antrum, nasolacrimal canals, teeth from the right second molar to the left second molar and the nasal septum.

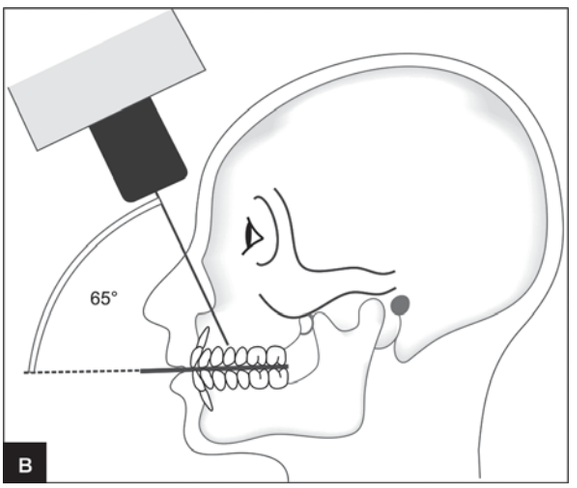
Film placement: The film is placed cross wise into the mouth and gently pushed back until it contacts the anterior border of the rami.

Projection of the central ray: The central ray is directed at a vertical angulation of +65° and a horizontal angulation of 0° towards the middle of the film.

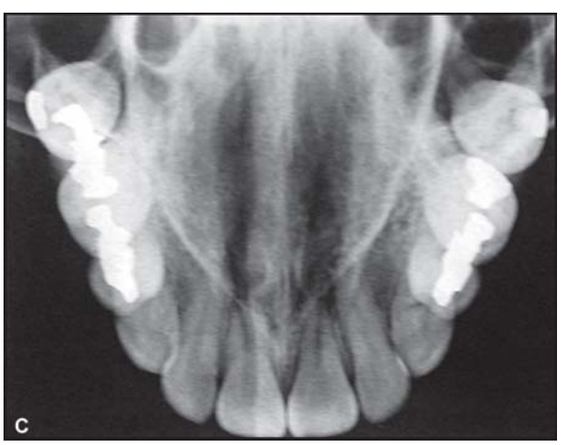
In general the central ray enters the patient's face through the Bridge of the Nose.



A. Image field



B. Projection of central ray with point of entry through the bridge of the nose



C. Maxillary cross-sectional occlusal view

Fig. 11.72: Maxillary cross-sectional view

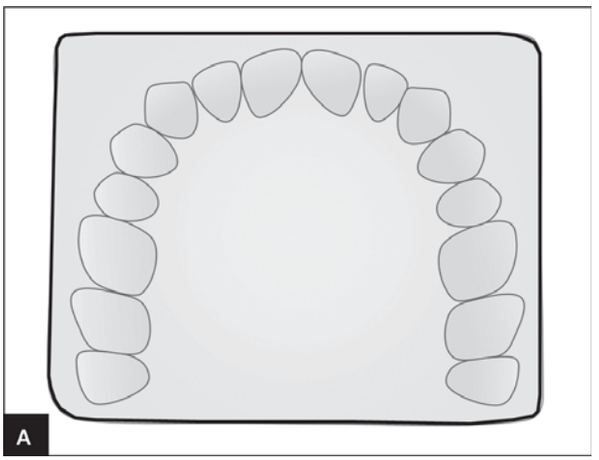
Maxillary Topographic View-Anterior (Fig. 11.73)

Image field: The primary field of this projection includes the anterior maxilla and it's dentition. It also includes the anterior floor of the nasal fossa and the teeth from canine to canine.

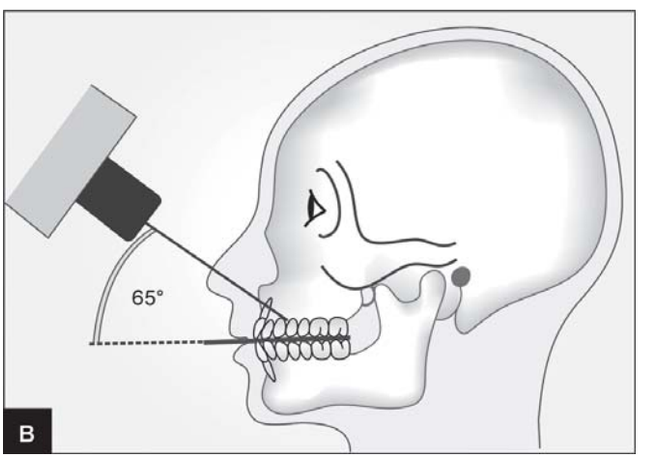
Film placement: The film is placed with the exposure side towards the maxilla and the long dimension crosswise in the mouth.

Projection of the central ray: The central ray is directed towards the middle of the film, the vertical angulation is +65° and horizontal angulation is 0°.

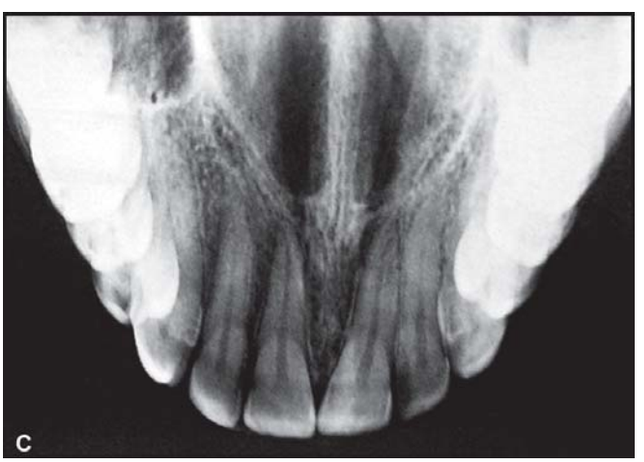
In general the central ray enters the patient's face approximately through the tip of the nose.



A. Image field



B. Projection of central ray with point of entry through the tip of the nose



C. Maxillary topographic anterior view

Fig. 11.73: Maxillary topographic anterior

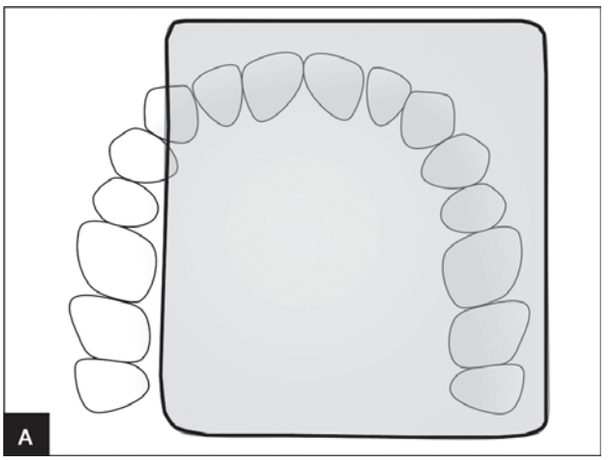
Maxillary Topographic View-Lateral (Fig. 11.74)

Image field: This projection shows half of the alveolar ridge of the maxilla, infero-lateral aspect of the antrum, the tuberosity and the teeth from the lateral incisor to the third molar.

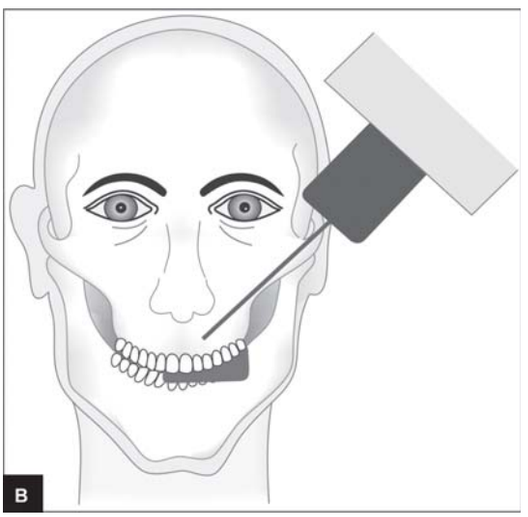
It may also show the zygomatic process of the maxilla superimposed with the roots of the molar teeth.

Film placement: The film is placed with it's long axis parallel to the sagittal plane and on the side of interest, with the pebbled side towards the maxilla in question. The lateral border should be positioned parallel to the buccal surfaces of the posterior teeth and extending laterally approximately 1/4th inch past the buccal cusps.

Projection of the central ray: The central ray is projected to a point 2 cm below the lateral canthus of the eye and directed towards the center of the film, with a vertical angulation of +60°.



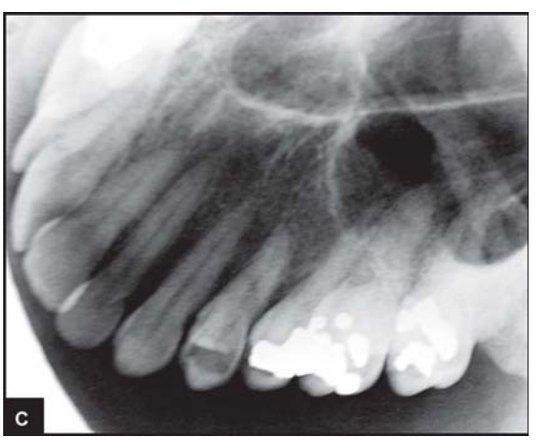
A. Image field



B. Projection of central ray with point of entry at a point approximately 2 cm below the lateral canthus of the eye

The vertex occlusal may be taken with an intraoral cassette containing intensifying screens. This technique is not preferred because of:

1. There is lack of detail and contrast on the film because of the intensifying screen, the mass of the tissue the X-ray beam has to penetrate and the consequent scatter.
2. The primary X-ray beam may be in direct line with the reproductive organs.
3. A relatively long exposure time is needed (approximately one second) despite the use of the intensifying screen.
4. There is direct radiation to the lens of the eye.
5. If the X-ray beam is positioned too far anteriorly, superimposition of the frontal bones may obscure the anterior part of the maxilla.



C. Maxillary topographic posterior view

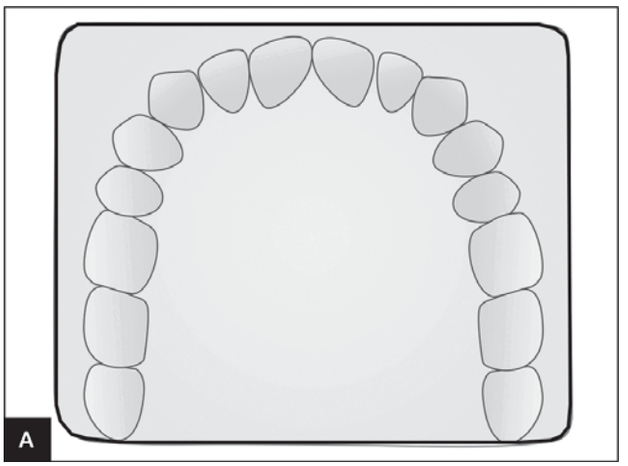
Fig. 11.74: Maxillary topographic posterior

Mandibular Cross Sectional View (Fig. 11.75)

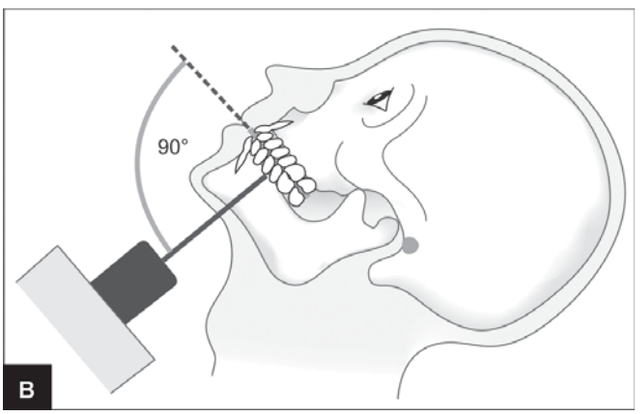
Image field: This projection includes soft tissues of the floor of the mouth and delineates the lingual and buccal plates of the jaw bone and the teeth from second molar to second molar.

Film placement: The film is placed in the mouth with its long axis perpendicular to the sagittal plane and the pebbled side towards the mandible. The anterior border of the film should be approximately ½ an inch anterior to the mandibular central incisors.

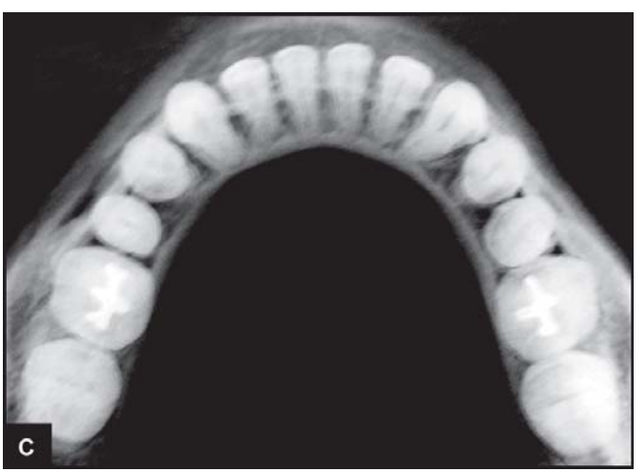
Projection of the central ray: It is directed at right angles to the center of the film. The point of entry is in the middle through the floor of the mouth approximately 3 cm below the chin.



A. Image field



B. Projection of central ray with point of entry at a point approximately 3 cm below the chin



C. Mandibular cross-sectional view

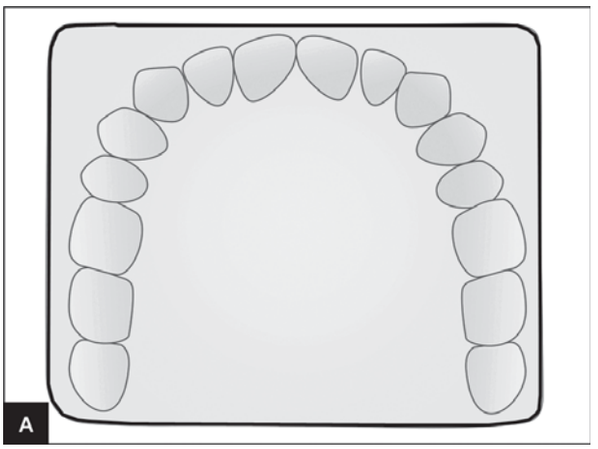
Fig. 11.75: Mandibular cross section

Mandibular Topographic View-Anterior (Fig. 11.76)

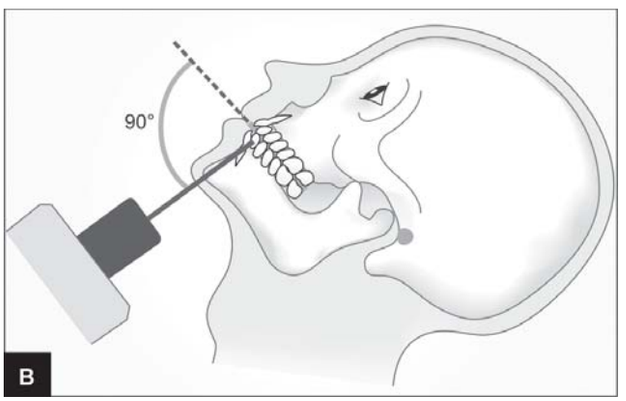
Image field: This projection depicts anterior portion of the mandible, the dentition from canine to canine and the inferior border of the mandible.

Film placement: The film is placed with the long axis parallel with the sagittal plane and as far posteriorly as possible, with the pebbled side down.

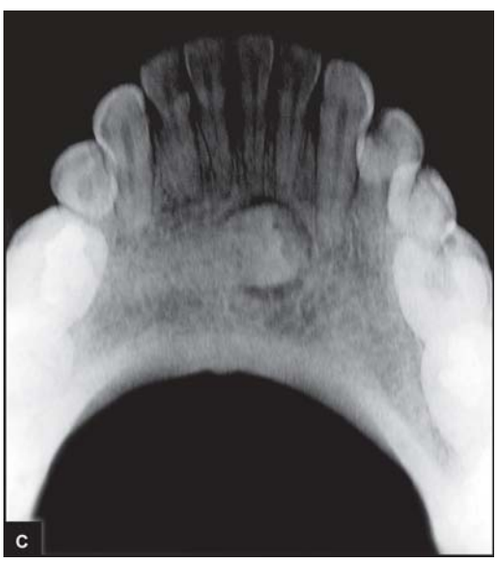
Projection of the central ray: The central ray is directed towards the middle of the film with –55° angulation in respect to the plane of the film. The point of entry of the central ray is in the midline and through the tip of the chin.



A. Image field



B. Projection of central ray with point of entry at the tip of the chin



C. Mandibular topographic anterior view

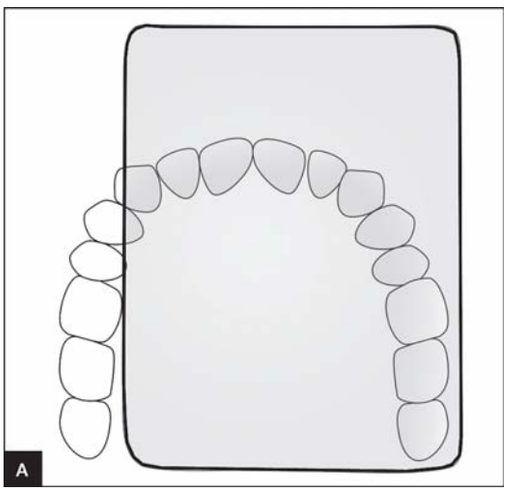
Fig. 11.76: Mandibular topographic anterior

Mandibular Topographic View-Lateral (Fig. 11.77)

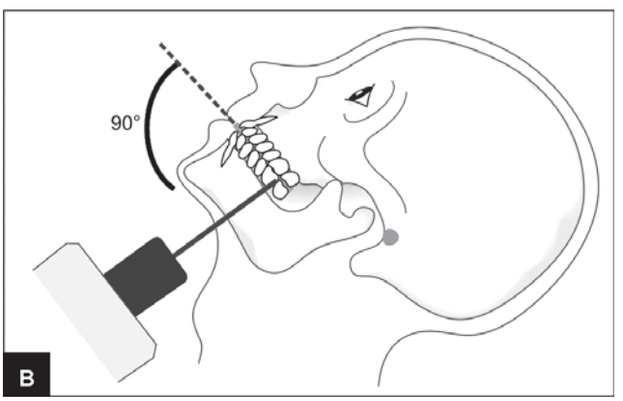
Image field: This projection covers soft tissues of half of the floor of the mouth, and the buccal and lingual cortical plates of half of the mandible and teeth from lateral incisor to the third molar.

Film placement: The film is placed length wise in the mouth with its long axis directed dorso-ventrally and the pebbled side towards the mandible. The film is placed as far back posterior as possible, so that the lateral border is parallel to the buccal surfaces of the posterior teeth and extending laterally approximately 1cm.

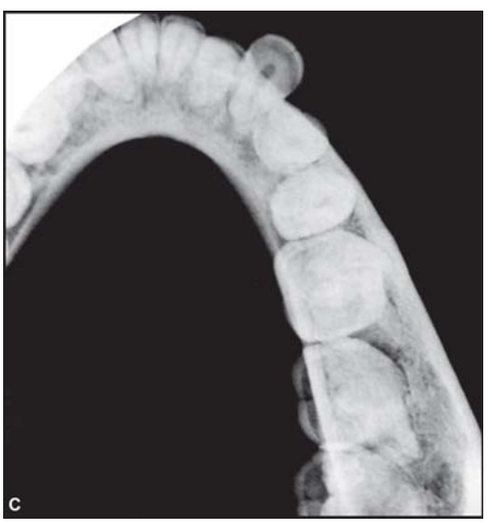
Projection of the central ray: The central ray is directed perpendicular to the center of the film. The point of entry of the central ray is beneath the chin and approximately 3 cm posterior to the chin and 3 cm lateral to the mid line.



A. Image field



B. Projection of central ray with point of entry beneath the chin, approximately 3 cm posterior to the chin and approximately 3 cm lateral to the midline



C. Mandibular topographic posterior view

Fig. 11.77: Mandibular topographic posterior

Intraoral Localization Techniques

These are methods used to locate the position of a tooth or an object in the jaws.

The dental radiograph is a two dimensional picture of a three dimensional object. It depicts the object in the superior-inferior and anterior-posterior relationship.

It fails to depict the buccolingual relationship or depth of the object.

Localization is used to over come this lacunae.

Indications

- Foreign bodies.
- Impacted teeth.
- Unerupted teeth.
- Retained roots.
- Salivary stones.
- Jaw fractures.
- Broken needles and instruments.
- Root positions.
- Filling materials.

Two Basic Methods Used to Localize Objects

1. Buccal Object Rule (Tube Shift Technique or Clark's Rule) – Figs 11.78 to 11.83.

   The basic principal is that the relative position of the radiographic images of two separate objects changes when the projection angle at which the projection was made is changed.

   A different horizontal angle is used when trying to locate vertically aligned images, e.g. root canals.

   A different vertical angulation is used when trying to locate a horizontally aligned image, e.g. mandibular canal.

   Method

   Two radiographs of the object are taken. First using the proper technique and angulations as prescribed and the second radiograph is taken keeping all other parameters constant and equivalent of those of the first radiograph, only changing the direction of the central ray either with a different horizontal or vertical angulation is used.

   Interpretation

   When the dental structure or object seen in the second radiograph appears to have moved in the same direction as the shift of the position indicating device (PID), the structure or the object in question is said to be positioned lingually.

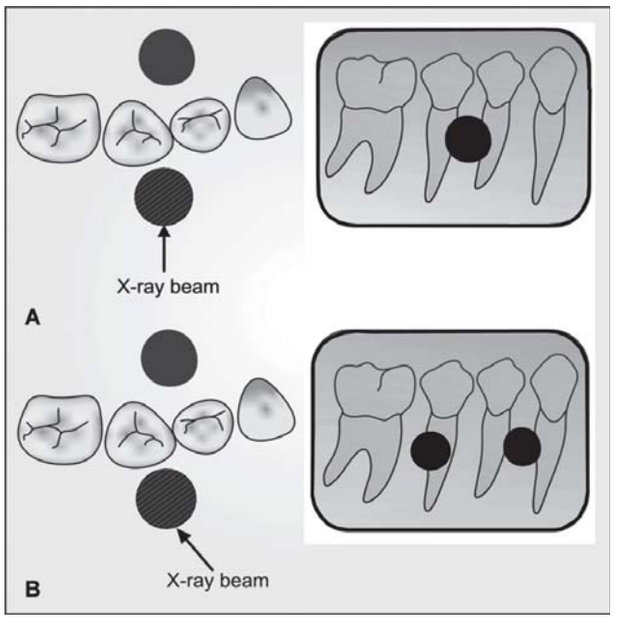


Fig. 11.78: Buccal and lingual objects shift positions when the direction of the X-ray beam is changed. **A.** Buccal (cross hatched circle) and lingual (black circle) are superimposed in the original radiograph. **B.** If the tube head is shifted in the mesial direction, the buccal object moves distally and the lingual object moves mesially (Same Direction =Lingual; Opposite Direction = Buccal)

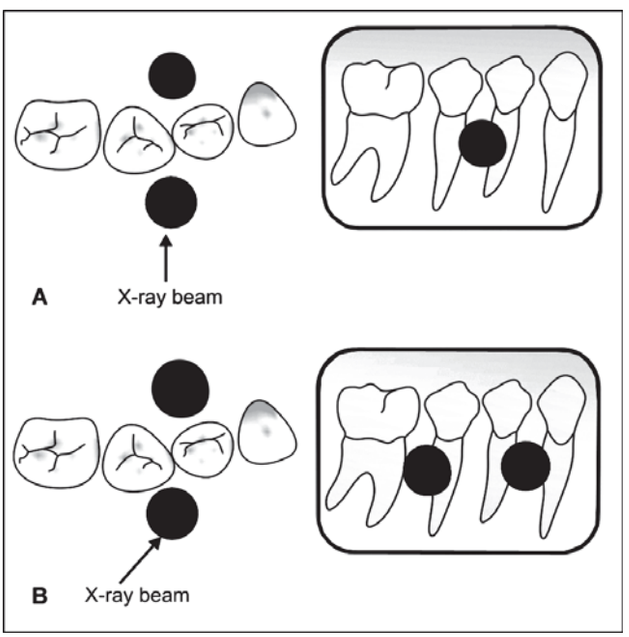


Fig. 11.79: Buccal and lingual objects shift positions when the direction of the X-ray beam is changed. **A.** Buccal (cross hatched circle) and lingual (black circle) are superimposed in the original radiograph. **B.** If the tube head is shifted in the distal direction, the buccal object moves mesially and the lingual object moves distally (Same Direction = Lingual; Opposite Direction = Buccal)

Fig. 11.80A: Radiograph of lower molars

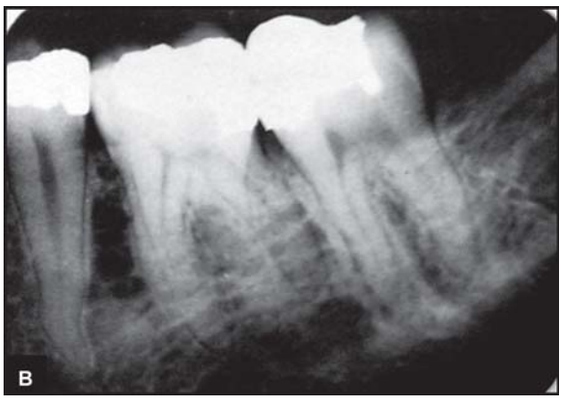


Fig. 11.80B: The radiograph is taken with a change in the horizontal angulation of the X-ray Cone so that the beam flow was towards the anterior arch. An extra root on the first molar which is buccally located (as it also moved to the anterior with the flow of the beam) can be seen

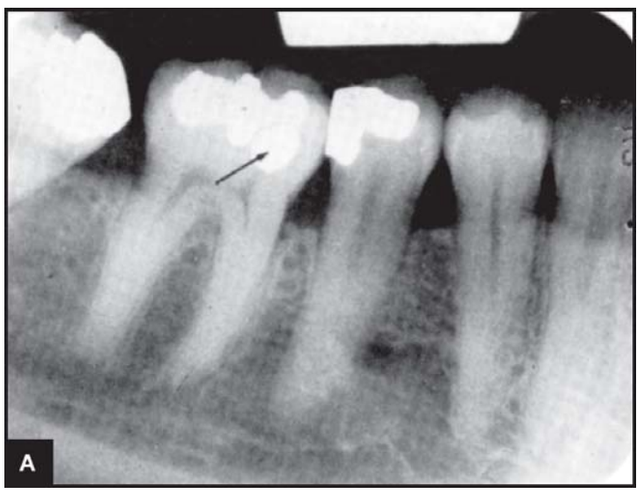


Fig. 11.81A: The arrow is pointing to a silver alloy. The radiograph was taken using a negative vertical angulation

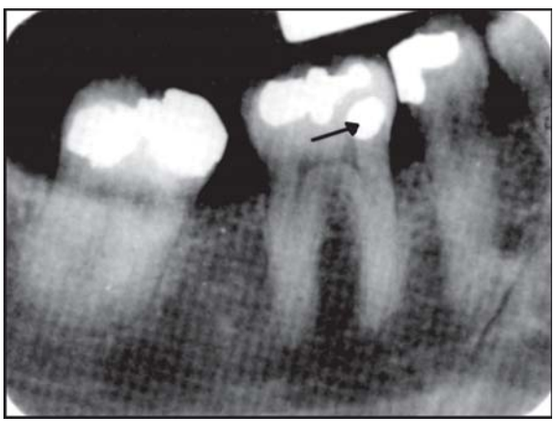


Fig. 11.81B: This radiograph was taken using a positive vertical angulation. The same alloy has separated from the occlusal silver alloy in the latter radiograph, and has moved in the same direction as the flow of the X-ray beam, and thus it is located bucally

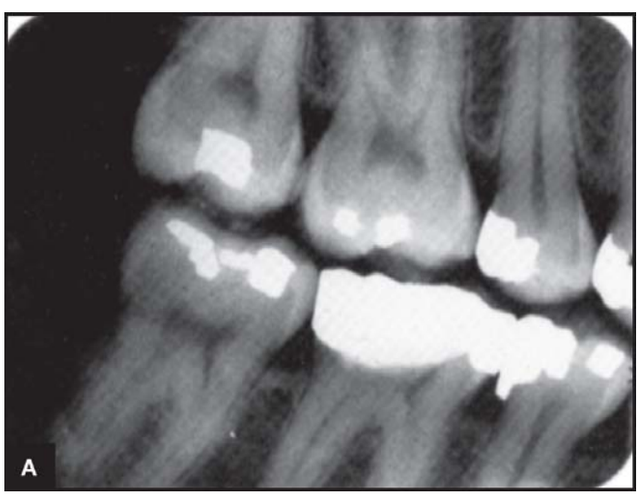


Fig. 11.82A: The buccal object rule works in the vertical plane. This radiograph was taken at a positive vertical angulation

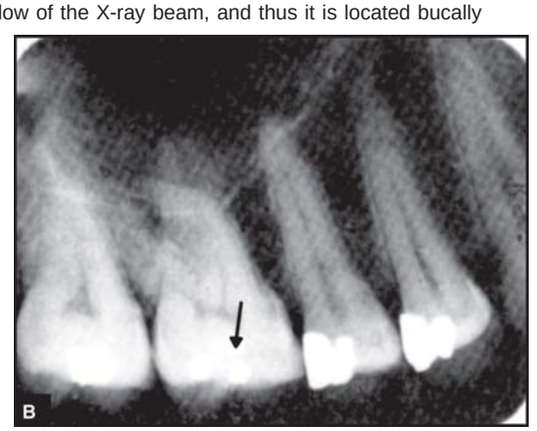


Fig. 11.82B: This radiograph was taken at a much higher positive vertical angulation. The arrow indicates that a small silver alloy is moving or shifting up instead of down. It is moving towards the source of radiation and not in the same direction as the beam flow. Hence the small silver alloy is lingually placed

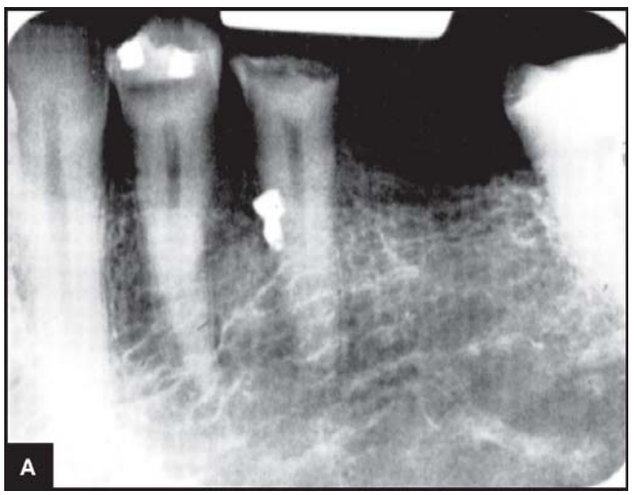


Fig. 11.83A: There is a radiopaque image located over the mesial proximal root surface of the second bicuspid

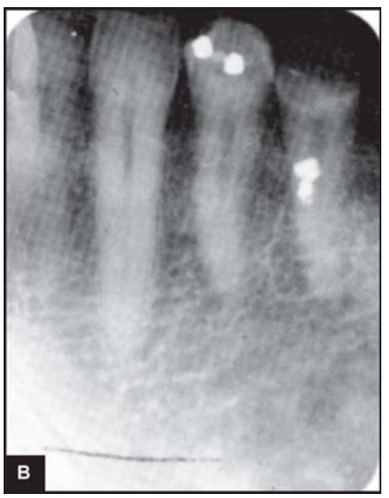


Fig. 11.83B: This is taken with a horizontal change of the X-ray cone. The X-ray beam was directed anteriorly, resulting in the radiopaque image moving slightly distal to the mesial root surface of the second bicuspid. Thus the radiopaque image is lingually located

But, if the object appears to have moved in a direction opposite to the shift of the PID, then the object is question is said to be positioned buccally.

SLOB rule: Same side Lingual. Opposite side Buccal.

2. *Right angle technique*

   Here two projections are taken at right angles to each other, which helps to localize an object in the maxilla or mandible.

   Method

   A periapical radiograph is taken to show the position of the object superio-inferiorly and anterio-posteriorly. Next, an occlusal radiograph is taken which will show the object's bucco-lingual and anterio-posterior relationship. The two radiographs when studied together help to localize the object in all three dimensions (Figs 11.84 and 11.85).

3. *Stereoscopy*: has been used to determine the location of small intracranial calcifications and multiple foreign bodies in dense or thick section, and in cases in which the interpretation of images produced at right angles might be difficult and to evaluate the relationships of margins of bony fractures.

   Stereoscopic imaging requires the exposure of two films, one for each eye, and thus delivers twice the amount of radiation to the patient. Between exposures the patient is maintained in position, the film is changed, and the tube shifted from the right eye to the left eye position. Although the magnitude of the tube shift is empiric, it is sufficient to form slightly different images. (A tube shift which is equal to 10% of the focal-film distance has been found to produce satisfactory results) After processing, the films are viewed with a stereoscope that uses either mirrors or prisms to coordinate the accommodation and convergence of the viewer's eyes so that the brain can fuse the two images.

   This technique is popular for the evaluation of bony pockets in patients with periodontal disease and morphology of the temporomandibular joint area, determination of root configuration of teeth that require endodontic therapy, assessment of the relationship of the mandibular canal to the roots of unerupted mandibular third molars, and the assessment of bone shape when the placement of dental implants is considered.

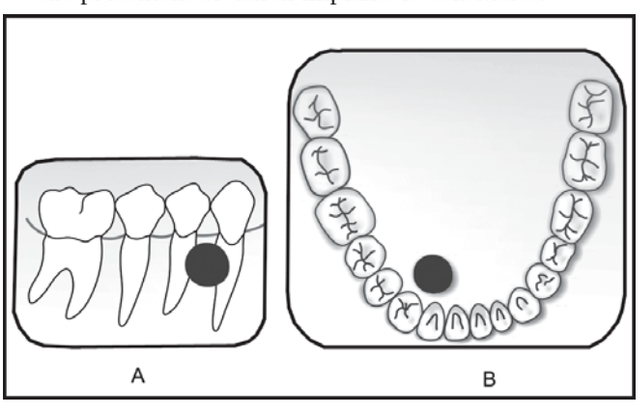


Fig. 11.84A and B: The right-angle technique **A.** The object appears to be located in bone on the periapical radiograph. **B.** The occlusal radiograph reveals that the object is actually located in the soft tissue lingual to the mandible

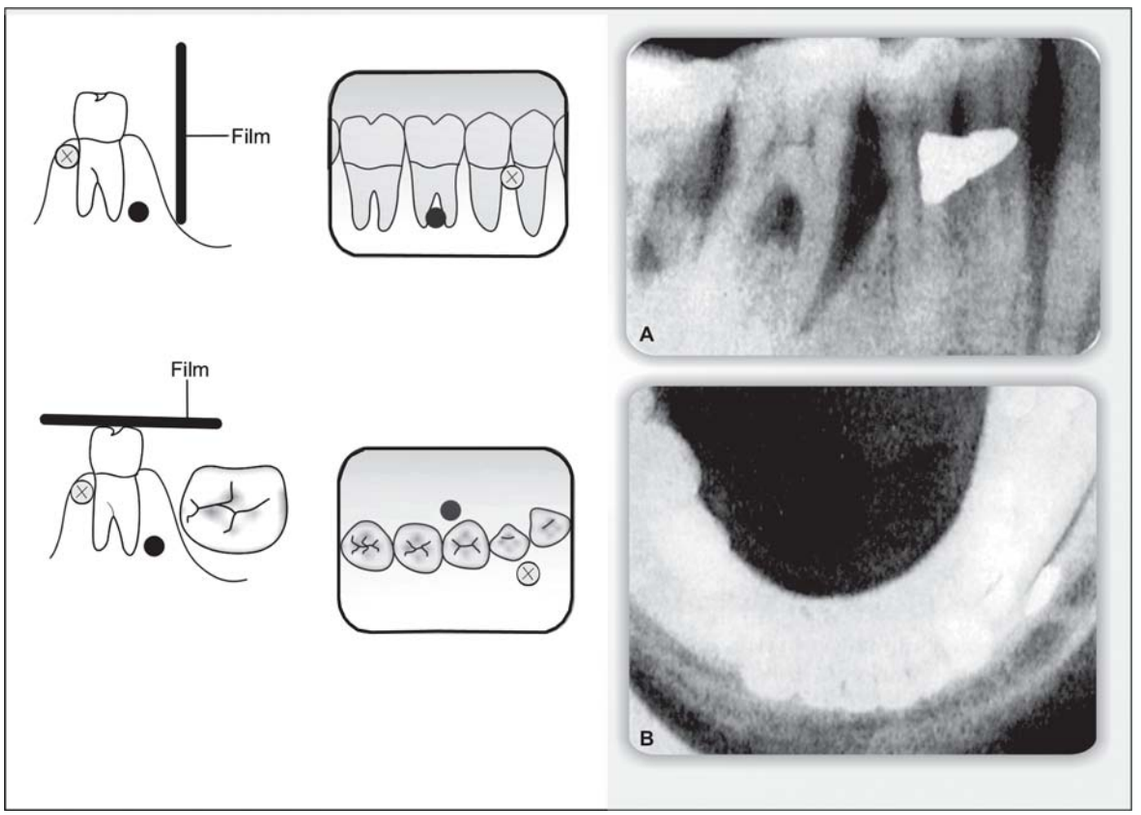


Fig. 11.85: Right angled localization technique. Two films are exposed at right angles to each other to identify the location of an object. The periapical radiograph (**A**) will demonstrate the superior inferior and anterior-posterior position of the objects. A cross-sectional occlusal radiograph (**B**) will demonstrate the anteroposterior and buccal lingual positions. Thus these two radiographs will demonstrate all three dimensions of an area, and the location of objects can be identified

Radiographic Techniques for Localization of Impacted Teeth and Foreign Bodies

Maxillary area

i. Incisor zone
   - Stereoscopic
   - Lateral profile
   - Occlusal

ii. Cuspid zone
   - Stereoscopic
   - Lateral profile
   - Occlusal

iii. Bicuspid and molar zone
   - Periapical
   - Occlusal

Mandibular area

i. Incisor zone
   - Periapical
   - Lateral profile
   - Occlusal

ii. Posterior zone
   - Periapical
   - Occlusal

iii. Third molar zone
   - Periapical
   - Lateral oblique
   - Oblique occlusal

BIBLIOGRAPHY

1. Frommer HH. Intraoral Radiographic Technique: The Paralleling Method in Radiology for Dental auxillaries, 6th edition St. Louis, Mosby- year book, 1996; 139-204.
2. Goaz PW, White SC. Intraoral Examination in Oral Radiology, Principles and Interpretation, 3rd ed. St. Louis, CV Mosby, 1994; 102-05: 151-212.
3. Johnson ON, McNally MA, Essay CE. The Periapical Examination Essentials of Dental Radiography for Dental Assistants and Hygienists, 6th ed. Norwalk, Appleton and Lange, 199; 319-90.
4. Mason-Hing LR. In Fundamentals of Dental Radiography, 3rd ed, Philadelphia, WB Saunders, 1993; 1-139.
5. Matteson SR, Whaley C, Secrist VC. Intraoral Radiographic Techniques, In Dental Radiology, 4th ed., Chapel Hill, University of North carolina Press, 1988; 77-105.

12

Extraoral Radiographic Techniques

These techniques imply that the film is placed outside the oral cavity, against the side of the face to be radiographed and the X-ray beam is directed towards it.

INDICATIONS

1. When it is not possible to place the film intraorally as during trismus.
2 To examine the extent of large lesions, especially when the area of pathology is greater than which can be covered by an intraoral periapical film.
3. When jaws or other facial bones have to be examined for evidence of disease lesions and other pathological conditions.
4. To evaluate skeletal growth and development.
5. To evaluate the status of impacted teeth.
6. To evaluate trauma.
7. To evaluate temporomandibular joint area.

DRAWBACKS

1. Magnification occurs due to the greater object to film distance used.
2. Details are not well-defined due to the use of cassettes and intensifying screens. For optimum balance between loss of image detail and reduction of patient exposure medium or high speed screen film combinations should be used.
3. Contrast is reduced as the secondary radiation produced by the soft tissues is more.

An important aspect of the extraoral radiography techniques is the immobilization of the patient's head. This is achieved by the use of various devices like, compression bands, head clamps, craniostat.

Definition of Some Extraoral Landmarks used for Patient Positioning: (Fig. 12.1)

The Median Plane of the Head: (Midsagittal Plane)

This is determined by a line that is coincident with the sagittal suture between the upper margins of the parietal bones, running from the top of the skull backwards.

In the lateral views the median plane is kept parallel with the cassette. In the postero-anterior and antero-posterior views, the median plane is kept at right angles to the film cassettes.

The Infraorbital Line

This line runs across the face from one infraorbital margin to the other.

In the true lateral position the infraorbital line is at right angles to the film.

This line is used in lieu of the interorbital line, which is not a definite line as the pupillary plane varies with the position of the pupils.

The Orbitomeatal Line (Canthomeatal Line)

This is an imaginary line from the outer canthus of the eye to the tragus of the ear.

This is known as the radiological base line and joins the upper edge of the auditory meatus with the outer canthus of the eye.

It differs from the Frankfurt horizontal line.

The Frankfort Horizontal Line

Is the line which runs from the most inferior portion of the infraorbital margin of the orbit to the highest point on the superior surface of the external auditory meatus.

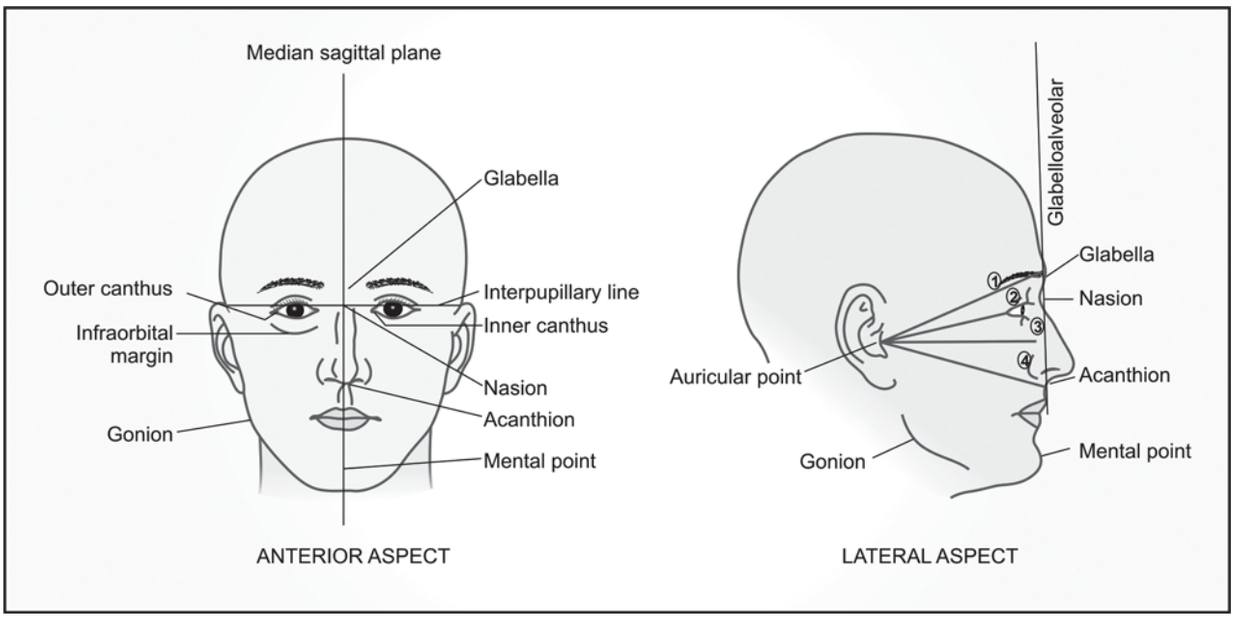


Fig. 12.1: Diagram showing external guide line used for patient positioning:
1. Glabellomeatal line, 2. Orbitomeatal line, 3. Inframeatal line, 4. Acanthomeatal line

IMPORTANT PARAMETRES

The film focus distance is of paramount importance. An increase in the focus film distance will improve the image sharpness, but adequate collimation must be used to prevent scattered radiation. Longer the film focus distance, the image is produced by more of the central rays, which in turn give minimum alteration in the true anatomical size.

This distance has no effect on the radiographic contrast obtained.

Most of the techniques for skull radiography use a film focus distance of approximately three feet (90 cm), in cephalometry a distance of five to six feet (150-180 cm) is used.

The centering point: The direction and angle of the central ray of the X-ray beam play an important and fundamental part in the clarity of the resultant shadow and the presence of distortion. It is useful to bear in mind the definite relationship to prominent and recognizable anatomical features and the central beam should be so directed as to pass or project away from the dense structures which would over shadow the required details.

REQUIRED EQUIPMENT

A. X-ray unit
   i. Intraoral X-ray machine
   ii. Extraoral X-ray machine
   iii. Panoramic X-ray unit
   iv. Cephalometry X-ray unit
B. Films
   i. Extraoral non-screen films
   ii. Extraoral screen films
      a. Sensitive to blue light
      b. Sensitive to green light
   iii. OPG films
C. Intensifying screens
   i. Blue light
   ii. Green light
D. Film cassettes
E. Grids.

Procedure

a. Equipment Preparation
   1. Load the extraoral cassette in the dark room under safe light conditions. Place one extraoral film between two intensifying screens and securely close the cassette.
   2. Set the exposure factors (kilo voltage, milliamperage, time) according to the manufacturer's recommendations.
   3. Load the cassette into the cassette carrier.
   4. Print in the date, patient's name, age, sex and the Case No.

b. Patient Preparation.
   1. Explain to the patient the radiographic procedure about to be performed.
   2. Place a lead apron without a lead collar over the patient and secure it. A double sided apron is recommended. The apron must be placed low around the back of the neck so that it does not block the X-ray beam. A thyroid collar is not recommended for extraoral radiography because it blocks part of the beam and obscures important diagnostic information.
   3. Remove all objects from the head and neck region that may interfere with film exposure. The patient must remove eyeglasses, earrings, necklaces, napkin chains, hearing aids, hairpins and complete or partial removable dentures or any other removable appliance in the oral cavity.

MOST COMMONLY USED VIEWS FOR MAXILLOFACIAL IMAGING

1. Posterioranterior Projection (also known as occipito frontal projection of Nasal Sinuses)

There are 2 methods for obtaining this projection.

A. Posterior Anterior (Granger Projection) Figs 12.2A and B.
B. Modified method, Inclined Posterior Anterior (Caldwell Projection) Fig. 12.3.

Radiography of the Maxillary Sinuses

1. Standard Occipitomental Projection (O° OM) (Figs 12.4A and B)
2. Modified Method (30° occipitomental projection) (Figs 12.5A and B)
3. PA Water's (Figs 12.6A to C)
4. Bregma Menton (Figs 12.7A and B)

Radiography of the Mandible

1. PA Mandible (Figs 12.8A and B)
2. Rotated PA Mandible (Figs 12.9A to C)
3. Lateral Oblique
   A. Anterior body of mandible (Figs 12.10A and B)
   B. Posterior body of mandible (Figs 12.10C and D)
   C. Ramus of mandible (Figs 12.11A and B)

Radiography of Base of the Skull

1. Submento Vertex projection (Figs 12.12A and B)

Radiography of the Zygomatic Arches

1. Jughandle view (A Modification of submento vertex view) (Fig. 12.13)

Radiography of the Temporomandibular Joint

1. Transcranial Projection (Figs 12.14A to D)
2. Trans Pharyngeal Projection (Figs 12.15A to C)
3. Trans Orbital Projection (Figs 12.16A to C)
4. Reverse Towne's Projection (Figs 12.17A and B)

Radiography of the Skull

1. Lateral cephalogram (Figs 12.18A to C)
2. True lateral (Figs 12.19A and B)
3. PA cephalogram (Figs 12.20A and B)
4. PA Skull (Figs 12.21A and B)
5. Towne's Projection (Figs 12.22A and C)

RADIOGRAPHY OF THE PARANASAL SINUSES

This is used to study the relationship of the sinuses to each other and to the surrounding structures. Lateral and/or antero-posterior view may be taken.

Routinely the paranasal sinuses are radiographed with the patient in the erect position, so as to demonstrate ably the presence or absence of fluid and in order to differentiate between the shadows caused by fluids and those caused by other pathology.

1. Posteroanterior Projection (also known as the Occipito Frontal Projection of the Nasal Sinuses)

There are two methods for obtaining this projection.

A. Posteroanterior (Granger) Projection (Figs 12.2A and B)

Structures Shown

This view is excellent for evaluating the inner and middle ear because the petrous pyramid can be viewed through the orbits. Frontal sinuses lying above the frontonasal suture, anterior ethmoidal cells lying each on either side of the nasal fossa, sphenoidal sinuses projected through the nasal fossa just below or between the shadows of the ethmoids. The upper part of the antrum is superimposed by dense shadows of the petrosae.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long axis of the cassette is positioned vertically.

Position of Patient

The midsagittal plane should be vertical and perpendicular to the plane of the cassette.

Only the forehead and nose should touch the cassette. The radiographic baseline is at 90 degrees to the film.

Central Ray

Is directed to the midline of the skull so that the X-ray beam passes through the canthomeatal plane perpendicular to the film plane.

Exposure Parameters

kVp- 65 mA-10 Seconds-3

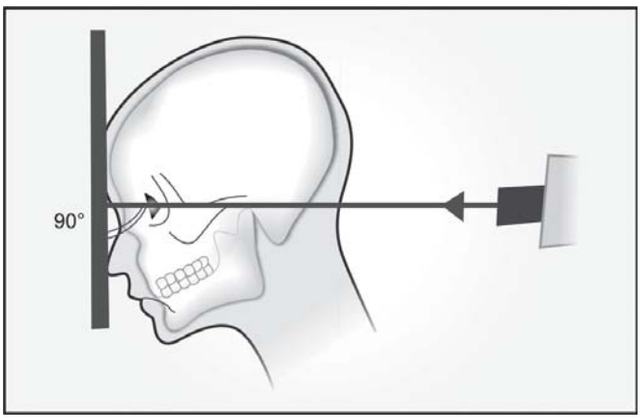


Fig. 12.2A: Diagram for the positioning for posteroanterior (Granger) projection

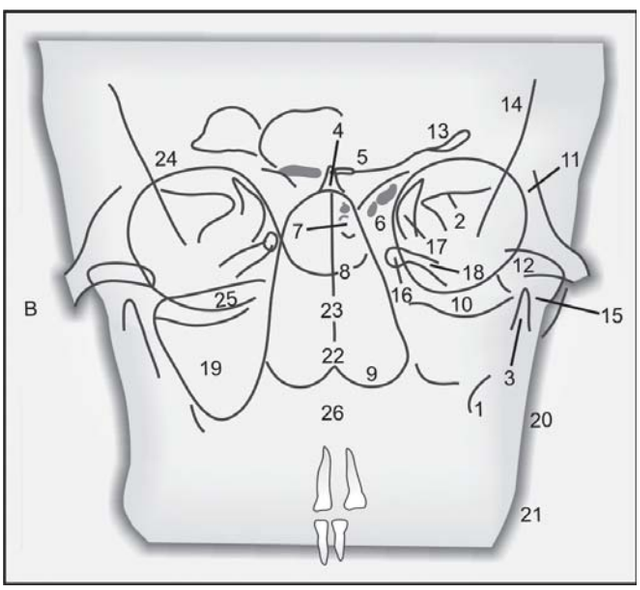


Fig. 12.2B: Labelled line diagram of Posteroanterior (Granger) view, showing important landmarks. 1. Maxillary tuberosity; 2. Petrous pyramid (houses inner ear); 3. Coronoid process; 4. Crista galli; 5. Dorsum sella; 6. Ethmoid air cells; 7. Sphenoid air cells; 8. Floor of the sphenoid sinus; 9. Floor of the nasal fossa; 10. Floor of the posterior cranial fossa; 11. Frontal process of zygoma; 12. Mandibular condyle; 13. Floor of the anterior cranial fossa; 14. Temporal surface of greater wing of sphenoid (linea innominata); 15. Mandibular neck; 16. Foramen rotundum; 17. Superior orbital fissure; 18. Inferior orbital fissure; 19. Maxillary antrum; 20. Mandibular ramus; 21. Mandibular angle; 22. Anterior nasal spine; 23. Nasal septum; 24. Supraorbital rim; 25. Infra orbital rim; 26. Anterior maxilla

B. Modified Method, Inclined Posteroanterior (Caldwell) Projection. (Fig. 12.3)

Structures Shown

This angulation will cause the petrous ridges to be superimposed on the maxillary sinuses, thus allowing more accurate examination of the orbits and ethmoidal air cells.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

The midsagittal plane is vertical and perpendicular to the cassette.

Only the forehead and nose touch the cassette, so that the canthomeatal line is perpendicular to the cassette. On the resultant radiograph the superior border of the petrous ridge is projected in the lower third of the orbit.

Central Ray

Is directed 23° to the canthomeatal line, entering the skull about 3 cm above the external occipital protuberance and exiting at the glabella .

Exposure Parameters

kVp- 65 mA-10 Seconds-3

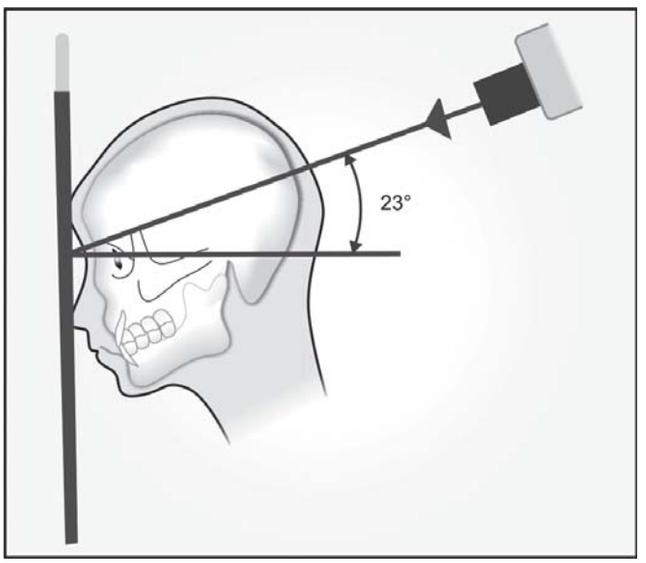


Fig. 12.3: Diagram of the positioning inclined posteroanterior (Caldwell) projection

RADIOGRAPHY OF THE MAXILLARY SINUSES

1. Standard Occipitomental Projection (0° OM) (Figs 12.4A and B)

Structures Shown

The projection shows the facial skeleton and the maxillary antra, and avoids superimposition of the dense bones of the base of the skull. It is especially useful to detect middle third fracture (Le Fort I,II,III, zygomatic complex, naso-ethmoidal complex, orbital blow out) and coronoid fractures.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

The midsagittal plane should be vertical and perpendicular to the plane of the cassette.

Only the nose and chin should touch the cassette. The head is tipped back so that the radiographic baseline is at 45° to the film.

Central Ray

Is directed horizontally through the occiput.

Exposure Parameters

kVp-65 mA-10 Seconds-2-3

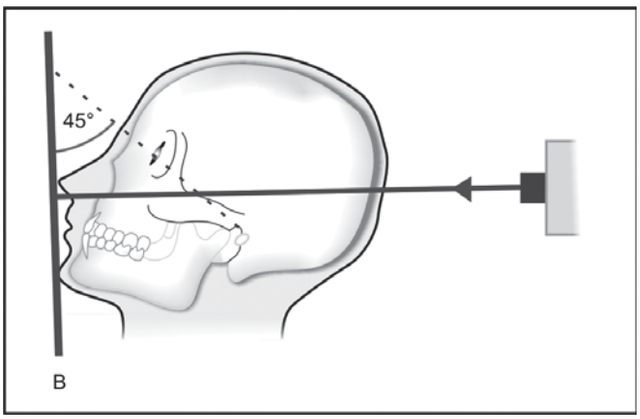


Fig. 12.4A: Diagram for the positioning of standard OM projection, the radiographic base line is at 45° to the film, and the X-ray beam is perpendicular to the film

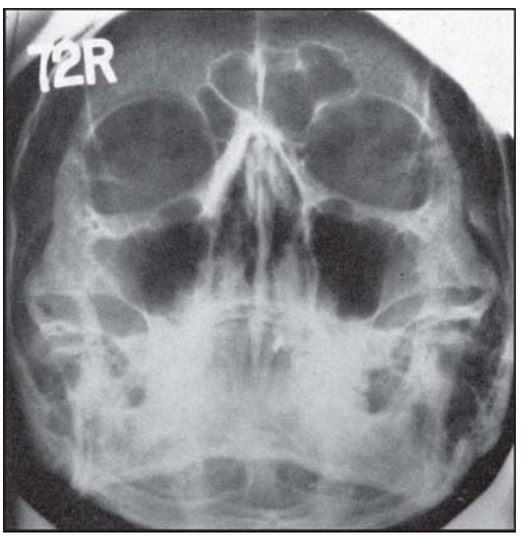


Fig. 12.4B: Standard occipitomental view

2. Modified Method (30° Occipitomental Projection) (Figs 12.5A and B)

Structures Shown

This projection shows the facial skeleton, from a different angle enabling certain bony displacements to be detected. It is useful in detecting middle third fractures (Le Fort I, II and III) and coronoid process fractures.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long axis of the cassette is positioned vertically.

Position of Patient

The midsagittal plane is vertical and perpendicular to the cassette.

The head is centered so that the nasion is in the center of the cassette.

Only the nose and chin touch the cassette, The head is tipped back so that the radiographic baseline is at 45° to the film.

Central Ray

Is directed 30° to the horizontal, centered through the lower border of the orbit.

Exposure Parameters

kVp- 65 mA-10 Seconds-2-3

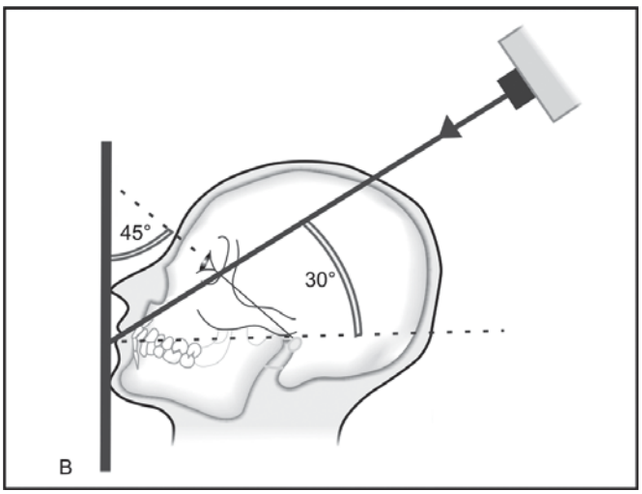


Fig. 12.5A: Diagram for the positioning of 30 degree OM projection, the radiographic base line is at 45 degrees to the film, and the X-ray beam is aimed downwards at 30 degrees

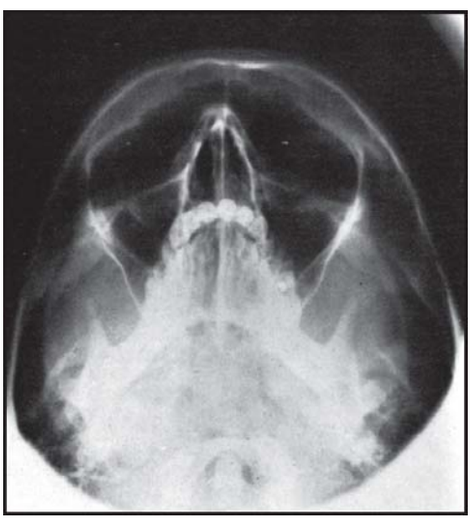


Fig. 12.5B: 30° occipitomental view

3. PA Water's (Fig. 12.6A to C)

Structures Shown

This projection is primarily used to demonstrate the maxillary sinus, frontal and ethmoidal sinuses.

The sphenoidal sinuses can be seen if the patient is asked to open his mouth, whereby the sphenoidal sinuses are projected on the palate.

The orbit, frontozygomatic suture, nasal cavity, coronoid process of the mandible and the zygomatic arch are also seen.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

The midsagittal plane should be vertical and perpendicular to the plane of the film.

The patient's head is extended so that only the chin touches the cassette.

The cassette is centered around the acanthion (anterior nasal spine).

The canthomeatal line should be at 37° to the plane of the film and the line from the external auditory meatus to the mental protuberance should be perpendicular to the film.

[In this position the aim is to extend the patient's head just enough so as to place the dense shadows of the petrosae immediately above the antral floors.

When the head is extended too little, the petrosal shadows are projected onto the lower part of the antrum.

When the head is extended too much the antral shadows are foreshortened and results in failure to show the antral floor.

Water's (1915) specified that the tip of the nose should be 0.5 to 1.5 cm away from the cassette, Mahoney (1930) found that the petrosal shadows can be correctly placed by adjusting the orbitomeatal line at 37° to the horizontal.

[An easy visual method is that a line extending from the external auditory meatus to the mental protuberance of the chin should be perpendicular to the cassette].

Central Ray

Is directed perpendicular and to the mid point of the film. It enters from the vertex and exists from the acanthion.

Exposure Parameters

kVp-65 mA-10 seconds-2-3

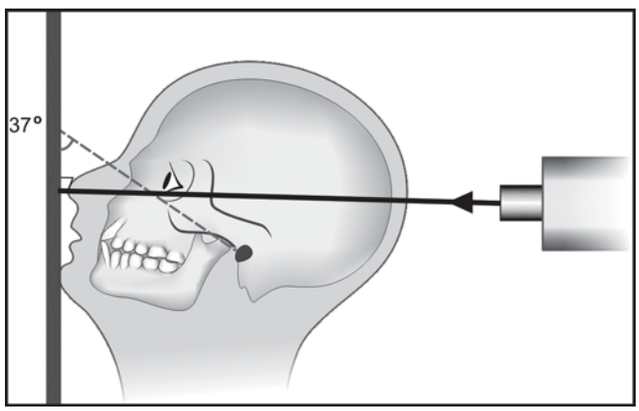


Fig. 12.6A: Diagram for the positioning of PA Water's projection, the radiographic base line is at 37° to the film, and the X-ray is perpendicular to the film

Fig. 12.6B: PA Water's view

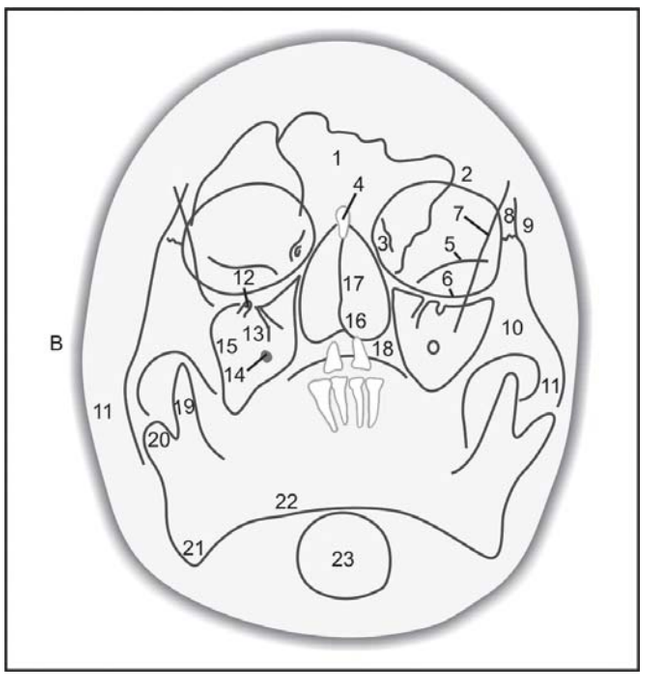


Fig. 12.6C: Labeled line diagram of PA Water's, showing important landmarks: 1. Frontal sinus; 2. Orbital roof (anterior margin); 3. Ethmoidal air cells 4. Crista galli; 5. Sphenoid ridge (posterior portion of orbital roof); 6. Orbital floor (anterior margin); 7. Linea innominata; 8. Zygomatic process of frontal bone; 9. Frontozygomatic suture; 10. Zygoma; 11. Zygomatic arch; 12. Infraorbital foramen; 13. Superior orbital fissure; 14. Foramen rotundum; 15. Maxillary sinus; 16. Anterior nasal spine; 17. Nasal septum; 18. Hard palate; 19. Coronoid process; 20. Mandibular condyle; 21. Mandibular angle; 22. Inferior border of mandible; 23. Foramen magnum

4. Bregma Menton (Figs 12.7A and B)

Structures Shown

This projection is primarily used to demonstrate the walls of the maxillary sinus (especially in the posterior areas), the orbits, the zygomatic arches and the nasal septum.

It also demonstrates medial or lateral deviations of any part of the mandible.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

The midsagittal plane should be vertical and perpendicular to the plane of the film.

The patient's head is extended as far as comfortable, to make the lower border of the mandible as parallel to the cassette as possible. Only the chin touches the cassette.

The canthomeatal line should also be approximately parallel to the plane of the film.

Central Ray

The central ray enters at the bregma and exits at the menton.

Exposure Parameters

kVp-65 mA-10 seconds-2-3

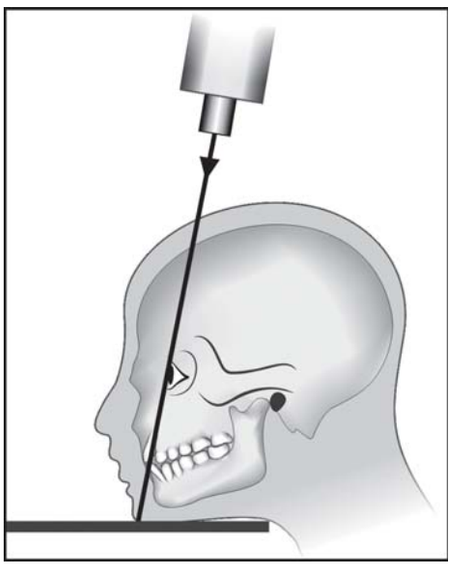


Fig. 12.7A: Diagram for the positioning of Bregma Menton projection, the chin is extended as far forward as possible

Fig. 12.7B: Bregma-menton view

RADIOGRAPHY OF THE MANDIBLE

1. PA Mandible: (Figs 12.8A and B)

Structures Shown

A postero-anterior projection of the mandibular body and the ramus. The central part of the body is not well seen because of the superimposition of the spine.

It is used to study fractures of the posterior third of the body of the mandible, angles, rami and lower condylar necks, medio-lateral expansion of the posterior third of the body or the rami in case of tumors or cystic lesions, maxillofacial deformities and mandibular hypoplasia or hyperplasia.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

The sagittal plane should be vertical and perpendicular to the film.

The head is tipped downwards so that the forehead and nose touch the film. The radiographic base line is horizontal and perpendicular to the film.

The film is adjusted so that the lips are centered to the film.

Central Ray

Is directed at right angles to the film through the midsagittal plane through the cervical spine, at the level of the angles of the mandible.

Exposure Parameters

kVp-65 mA-10 Seconds-2-3

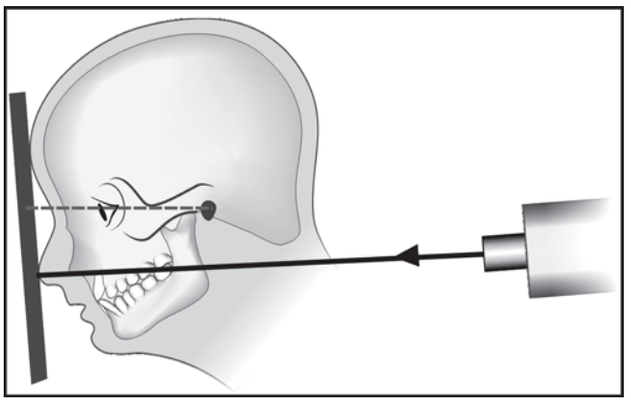


Fig. 12.8A: Diagram for the positioning of PA mandible projection, the radiographic base line and the X-ray beam are perpendicular to the film

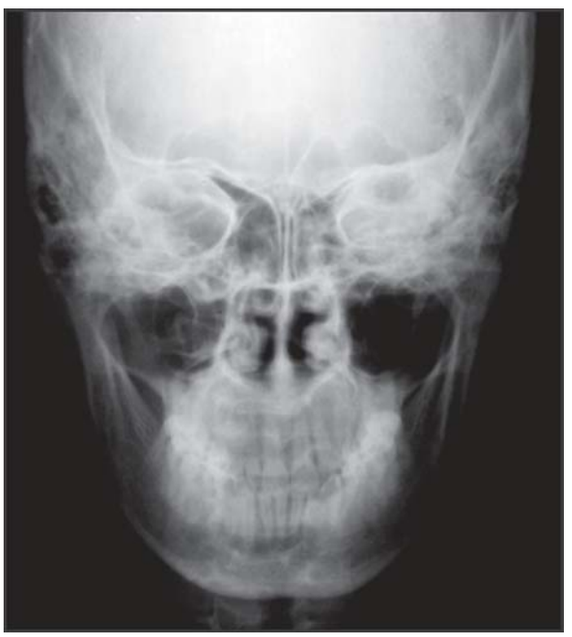


Fig. 12.8B: PA mandible view

2. Rotated PA Mandible: (Figs 12.9A to C)

Structures Shown

This projection is used to show the tissues of one side of the face and used to investigate the parotid gland and the ramus of the mandible. It is mainly used to demonstrate, stones or calculi in the parotid, to note the medio-lateral expansion of lesions in the ramus and submasseteric infections.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

The patient is positioned facing the film, with the occlusal plane horizontal and the tip of the nose touching the film.

The head is rotated 10° to the side of interest. This rotates the bones of the back of the skull away from the side of the face under investigation.

Central Ray

Is directed at right angles to the film, aimed down the side of the face which is of interest.

Exposure Parameters

kVp-60 mA-7 Seconds-2

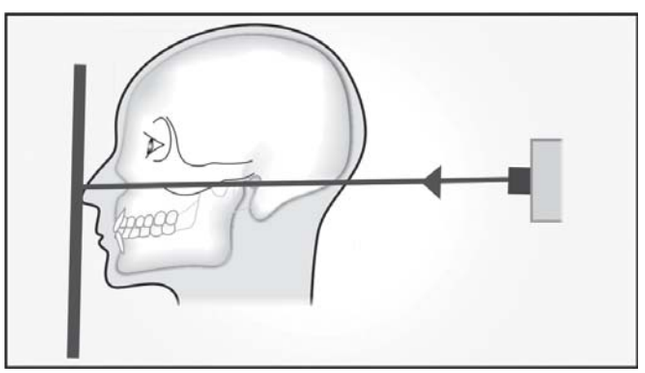


Fig. 12.9A: Diagram for positioning rotated postero-anterior, from the side, normal head position and the X-ray beam horizontal to the film

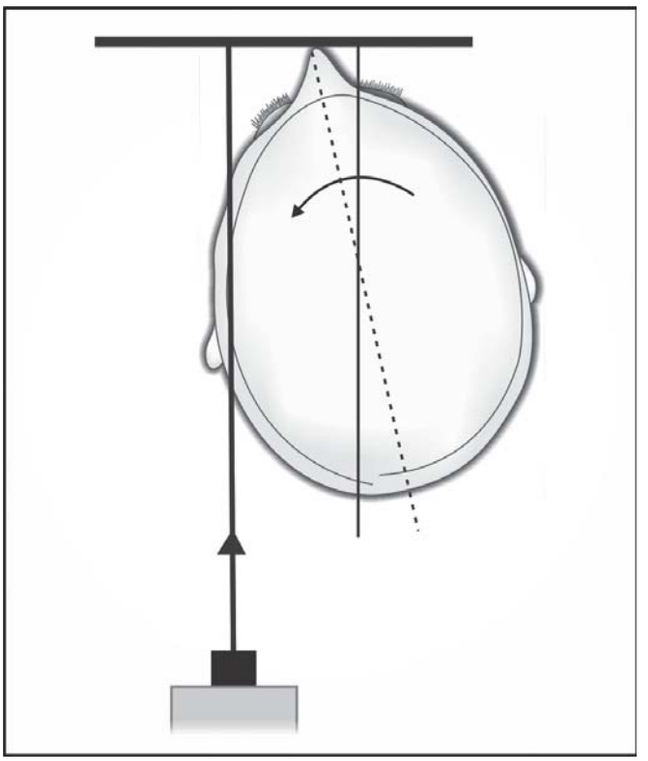


Fig. 12.9B: Diagram for positioning rotated postero-anterior, from above, 10° rotation of the head to the side of interest and the X-ray beam aimed along the side of the face

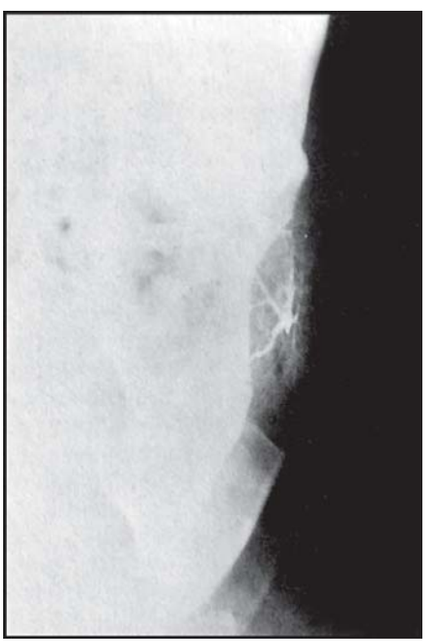


Fig. 12.9C: Rotated postero-anterior view showing parotid sialography, with the central ray passing through the glands

3. Lateral Oblique

A. Anterior Body of the Mandible (Figs 12.10A and B)

Structures Shown

Anterior body of the mandible, position of the teeth in the same area. Helps to evaluate impacted teeth, fractures and lesions located in the inferior border of the mandible.

Film Placement

The cassette is placed flat against the patient's cheek and is centered over the body of the mandible,overlying the canine teeth. The cassette also should be positioned parallel to the body of the mandible. The patient must hold the cassette in position with the thumb placed under the edge of the cassette and the palm against the outer surface of the cassette.

Position of Patient

The patient's head is so adjusted, that the ala tragus line is parallel to the floor.

The mandible is protruded slightly to separate it from the vertebral column. The cassette is placed over the patient's cheek and centered over the area of interest.

The inferior border of the cassette should be parallel to the lower border of the mandible and below it.

The sagittal plane is tilted so that it is 5° to the vertical, and rotated 30° from the true lateral position.

For the bicuspid and incisor region, the patient's head can be turned slightly away from the tube so that the nose and chin approximate the cassette.

Central Ray

Is directed from under the mandible opposite the side of examination, from 2 cm behind the angle of the mandible. The beam is directed upward (–10° to –15°) and centered on the anterior body of the mandible. The beam must be directed perpendicular to the horizontal plane of the film.

Exposure Parameters

kVp- 65-70 mA-7-10 Seconds-0.8

Fig. 12.10A: Diagram for the positioning of lateral oblique projection for anterior body of the mandible, film is in contact with the cheek at the canine area, and the X-ray beam aims at the canine area, through the radiographic key hole

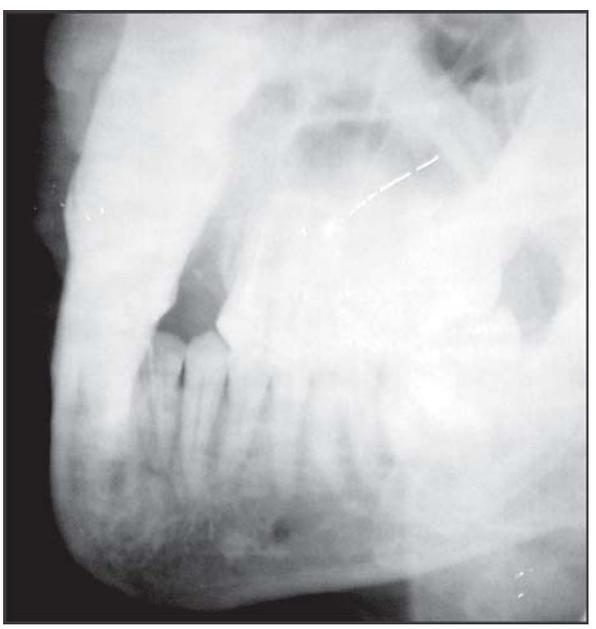


Fig. 12.10B: Lateral oblique for the body of the anterior mandible

B. Posterior Body of the Mandible (Figs 12.10C and D)

Structures Shown

Body of the mandible, position of the teeth in the same area, ramus of the mandible, angle of the mandible. Helps to evaluate impacted teeth, fractures and lesions located in the inferior border of the mandible.

Film Placement

The cassette is placed flat against the patient's cheek and is centered over the body of the mandible. The cassette also should be positioned parallel to the body of the mandible. The patient must hold the cassette in position with the thumb placed under the edge of the cassette and the palm against the outer surface of the cassette.

Position of Patient

The patient's head is so adjusted, that the ala tragus line is parallel to the floor.

The mandible is protruded slightly to separate it from the vertebral column. The cassette is placed over the patient's cheek and centered over the area of interest.

The inferior border of the cassette should be parallel to the lower border of the mandible and below it.

The sagittal plane is tilted so that it is 5° to the vertical and the head is rotated 10° to 15° from the true lateral position.

For the molar and ramus region, the head should not be turned away from the tube as this will place the ramus behind the vertebral column.

Central Ray

Is directed from under the mandible opposite the side of examination, from 2 cm below the angle of the mandible. The beam is directed upward (–10° to –15°) and centered on the body of the mandible. The beam must be directed perpendicular to the horizontal plane of the film.

Exposure Parameters

kVp- 65-70 mA- 7-10 Seconds- 0.8

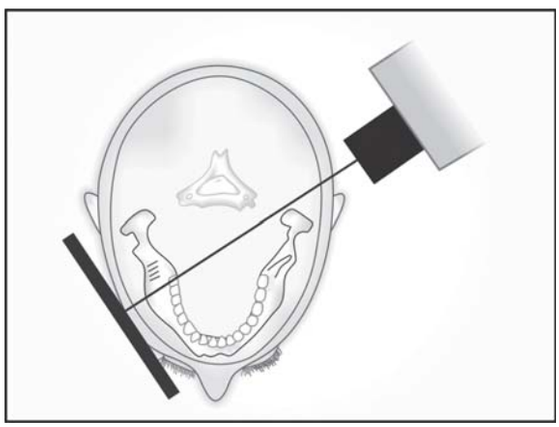


Fig. 12.10C: Diagram for the positioning of lateral oblique projection for posterior body of the mandible, film is in contact with the cheek at the premolar area, and the X-ray beam aims at the premolar area, through the radiographic key hole

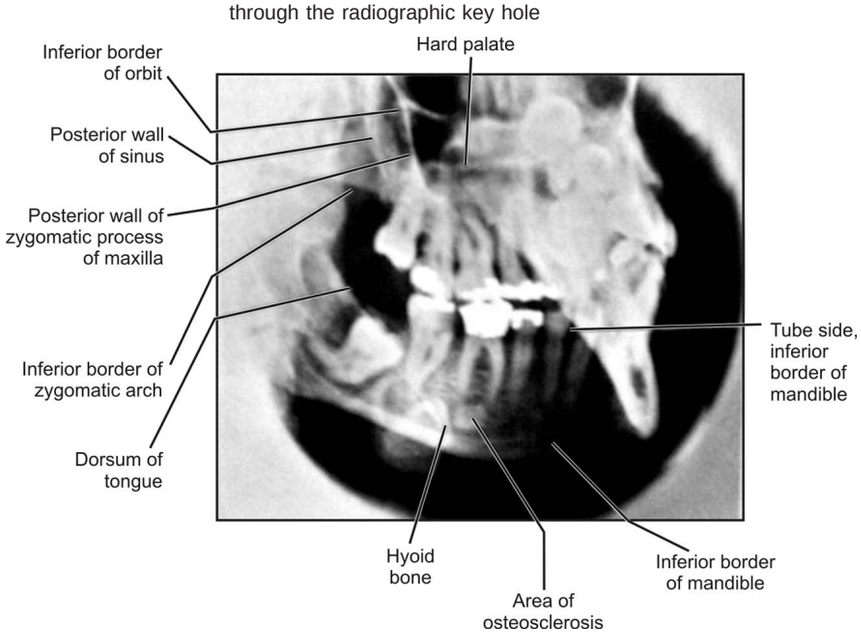


Fig. 12.10D: Anatomic landmarks identified in the oblique lateral projection of the mandibular body

C. Ramus of Mandible. (Figs 12.11A and B)

Structures Shown

The purpose of this view is to evaluate impacted third molars, large lesions, fractures that extend into the ramus of the mandible. This projection demonstrates a view of the ramus from the angle of the mandible to the condyles.

Film Placement

The cassette is placed flat against the patient's cheek and is centered over the ramus of the mandible. The cassette also should be positioned parallel to the ramus of the mandible. The patient must hold the cassette in position with the thumb placed under the edge of the cassette and the palm against the outer surface of the cassette.

Position of Patient

The patient's head is so adjusted, that the ala tragus line is parallel to the floor.

The mandible is protruded slightly to separate it from the vertebral column. The cassette is placed over the patient's cheek and centered over the area of interest.

The inferior border of the cassette should be parallel to the lower border of the mandible and below it.

The sagittal plane is tilted so that it is 10° to the vertical and the head is rotated 5° from the true lateral position.

Central Ray

Is directed from under the mandible opposite the side of examination, from behind the angle of the mandible to a point posterior to the third molar region on the side opposite the cassette. The beam is directed upward (–10° to –15°) and centered on the ramus of the mandible. The beam must be directed perpendicular to the horizontal plane of the film.

Exposure Parameters

kVp- 65-70 mA-7-10 Seconds-0.8

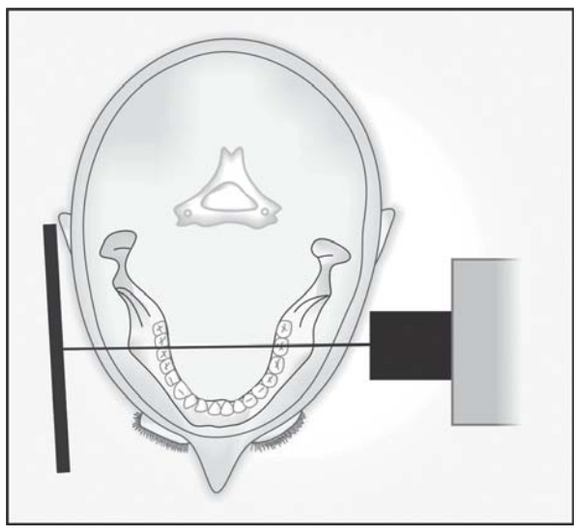


Fig. 12.11A: Diagram for the positioning of lateral oblique projection for ramus of the mandible, film is in contact with the cheek at the ramus area, and the X-ray beam aims at the ramus area, between the cervical spine and mandibular ramus

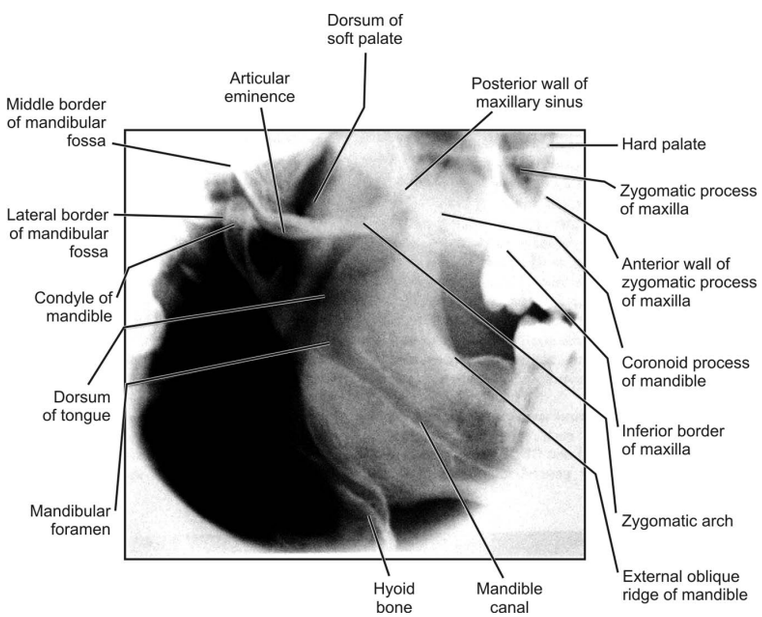


Fig. 12.11B: Anatomic landmarks identified in the oblique lateral projection of the mandibular ramus

RADIOGRAPHY OF THE BASE OF THE SKULL

1. Submentovertex Projection (Figs 12.12A and B)

Structures Shown

A full axial view of the base of the cranium showing a symmetrical projection of the petrosa, the mastoid process, foramen ovale, spinosum canals, carotid canals, sphenoidal sinuses, mandible, maxillary sinus, nasal septum, odontoid process of the atlas and the entire atlas, axial inclination of the mandibular condyles.

Helps to study destructive/expansile lesions affecting the palate, pterygoid region or base of the skull, sphenoidal sinus.

Film Placement

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is placed horizontally.

Position of Patient

The head is centered on the cassette, with the patient's head and neck tipped back as far as possible, the vertex (top) of the skull touches the cassette. Both the midsagittal plane should be perpendicular to the plane of the film and the radiographic base line should be parallel to the film.

Central Ray

Is directed perpendicular to the film.

It enters through the midsagittal plane, between the angles of the mandible and in a coronal plane 3/4th inches anterior to the external auditory meatus.

In order to view the petrous portion, the central ray is directed at right angles (or 5° to the horizontal) to the film midway between the external auditory meatus.

Exposure Parameters

kVp-50 mA-20-30 Seconds-0.4

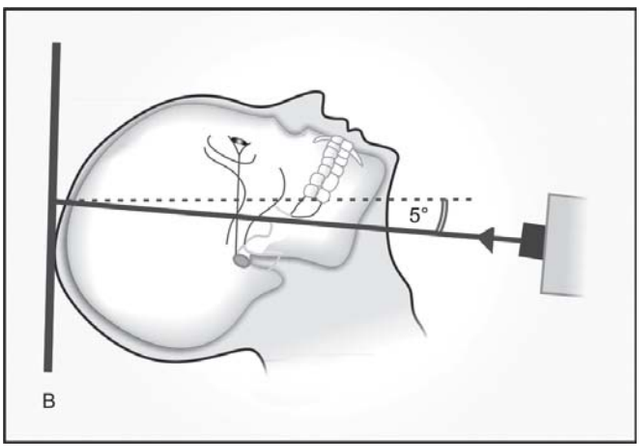


Fig. 12.12A: Diagram for the positioning of submentovertex projection, the radiographic base line is parallel to the film, and the X-ray is perpendicular to the film

Fig. 12.12B: Submentovertex view

RADIOGRAPHY OF THE ZYGOMATIC ARCHES

1. Jug Handle View (A Modification of the Submentovertex View) (Fig. 12.13)

Structures Shown

A symmetrical axial view of the zygomatic arches.

Film Position

Same as that in submentovertex.

Position of Patient

Same as that in submentovertex.

Central Ray

The cone is brought as close as possible to the patient (which leads to magnification of the structures at the base of the skull).

Exposure Parameters

kVp- less than 50 mA-20-30 Seconds-0.4

The exposure time for the zygomatic arch is reduced to approximately one-third the normal exposure time for a submentovertex projection.

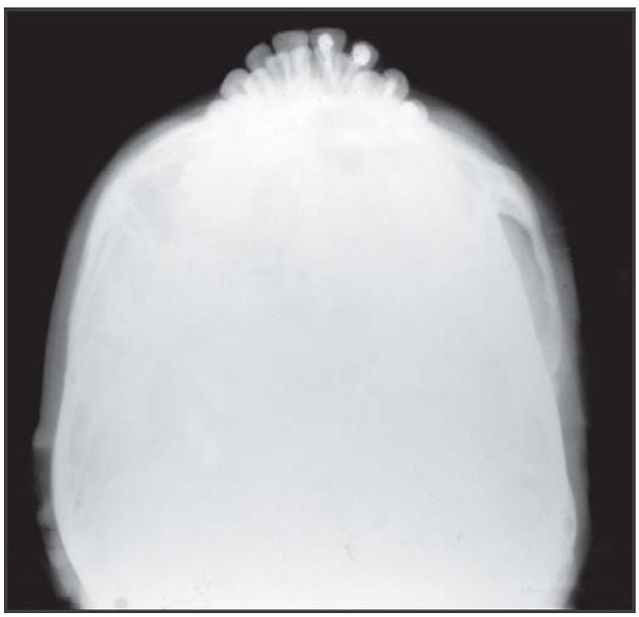


Fig. 12.13: Jug handle view

RADIOGRAPHY OF THE TEMPORO MANDIBULAR JOINTS

1. Transcranial (Figs 12.14A to D)

Structures Shown

This technique is most useful in detecting arthritic changes on the articular surface. It helps to evaluate the joint's bony relationship. Changes on the central and medial surfaces are not seen.

Film Position

The cassette is placed flat against the patient's ear and centered over the TM joint of interest, against the facial skin parallel to the sagittal plane.

Position of Patient

The patient's head is adjusted so that the sagittal plane is vertical.

The ala tragus line is parallel to the floor.

This view is taken with the patient's mouth in three positions: 1. Open mouth. 2. Rest position. 3. Closed mouth.

Central Ray

The point of entry is different according to the technique used:

A. *Post auricular or Lindblom technique*
   Point of entry of the central ray is ½" behind and 2" above the auditory meatus.
   [According to Lindblom the central ray should be directed from posteriorly so that it passes along the long axis of the condyle. (The medial pole of the condyle is more posterior to the lateral pole).

B. *Grewcock approach*
   The central ray enters through a point 2" above the external auditory meatus.

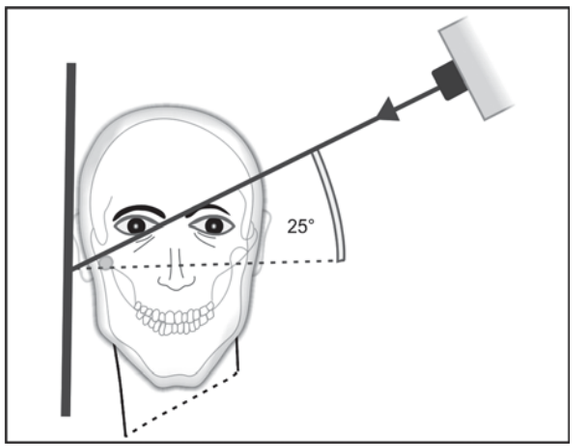


Fig. 12.14A: Transcranial projection, the central ray is oriented at 25° positive angle from the opposite side and anteriorly 20°, centered over the TMJ of interest, mouth closed

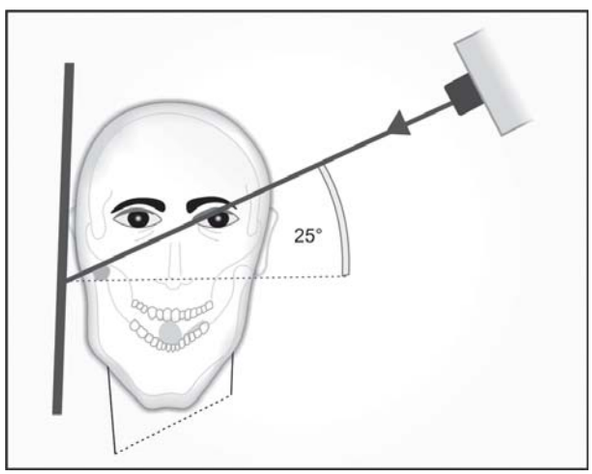


Fig. 12.14B: Transcranial projection, the central ray is oriented at 25° positive angle from the opposite side and anteriorly 20°, centered over the TMJ of interest, mouth open

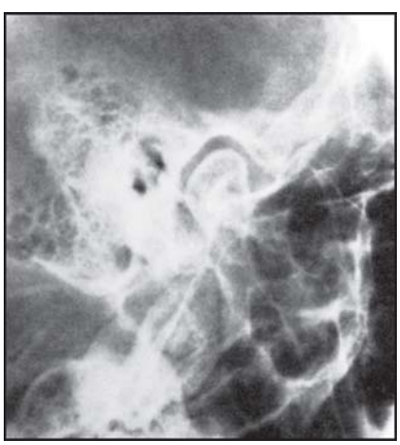


Fig. 12.14C: Transcranial view mouth closed position

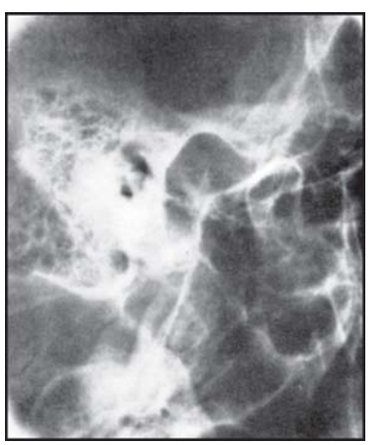


Fig. 12.14D: Transcranial view mouth open position

C. *Gill's approach*

The central ray enters through a point ½" anterior and 2" above the external auditory meatus.

In all the three techniques the central ray is directed caudally at an angle of +20° to +25°.

The point of exit is through the TM joint of interest.

Exposure Parameters

kVp-70 mA-07 Seconds-1.5

2. Transpharyngeal (Infracranial or McQueen Dell Technique) (Figs 12.15A to C)

Structures Shown

This view is a lateral projection of the condylar head and neck, usually taken in the mouth open position, so that the joint is projected into the shadow of air containing spaces of the nasopharynx, which helps to increase the contrast of the various parts of the joint.

Film Placement

The cassette is placed flat against the patient's ear and is centered to a point ½" anterior to the external auditory meatus, over the TM joint of interest, against the facial skin parallel to the sagittal plane.

Position of Patient

The patient is positioned so that the sagittal plane is vertical and parallel to the film, with the TM joint of interest adjacent to the film.

The film is centered to a point ½" anterior to the external auditory meatus.

The occlusal plane should be parallel to the transverse axis of the film so that the soft parts of the nasopharynx are in one line with the TM joint.

The patient is instructed to slowly inhale through the nose during exposure, so as to ensure filling of the nasopharynx with air during the exposure.

The patient should open his mouth so that the condyles move away from the base of the skull and the mandibular notch of the opposite side is enlarged.

Central Ray

Is directed from the opposite side cranially, at an angle of –5° to –10° posteriorly.

It is directed through the mandibular notch, that is a window between the coronoid, condyle and the zygomatic arch, of the side below the base of the skull to the TM joint of interest.

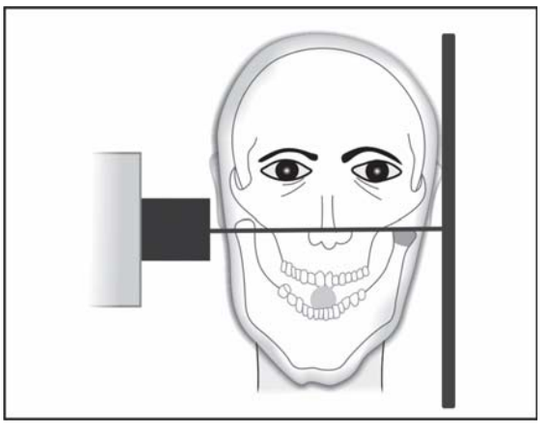


Fig. 12.15A: Transpharyngeal projection. The central ray is oriented superiorly 5° to 10° and posteriorly approximately 10°, centered over the TMJ of interest. The mandible is positioned at maximal opening

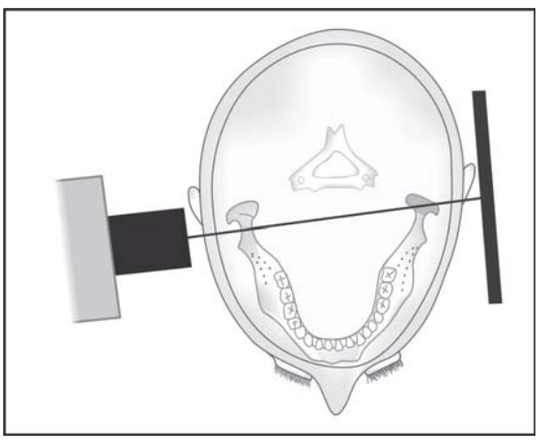


Fig. 12.15B: Transpharyngeal projection, showing positioning from above, showing the X-ray beam aimed slightly posteriorly across the pharynx

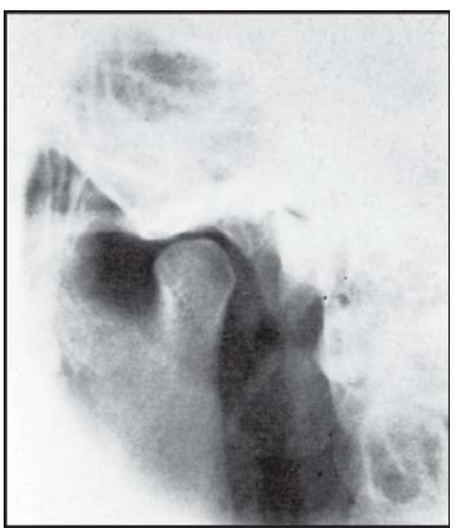


Fig. 12.15C: Transpharyngeal view

Exposure Parameters

kVp- 70 mA-07 Seconds-0.8

Parma Modification

The lead lined open ended cone is removed and the tube head is brought close to the skin surface, producing magnification of the tube side structures and there by reducing super imposition.

3. Transorbital (Zimmer Projection) (Figs 12.16A to C)

This is the conventional frontal TM joint projection which is most successful in delineating the joint with minimal super impositions, leading to the production of a relatively true 'enface' projection.

Structures Shown

The articular surface (convex) and the articular eminence (flat or convex).

Film Position

The film is positioned behind the patient's head at an angle of 45° to the sagittal plane.

Position of Patient

The patient is positioned so that the sagittal plane is vertical. The canthomeatal line should be 10° to the horizontal, with the head tipped downwards.

The mouth should be wide open.

Central Ray

The tube head is placed in front of the patient's face.

The central ray is directed to the joint of interest, at an angle of +20°, to strike the cassette at right angles.

The point of entry may be taken at:

A. Pupil of the same eye, asking the patient to look straight ahead.
B. Medial canthus of the same eye.
C. Medial canthus of the opposite eye.

Exposure Parameters

kVp-70 mA-07 Seconds-0.8

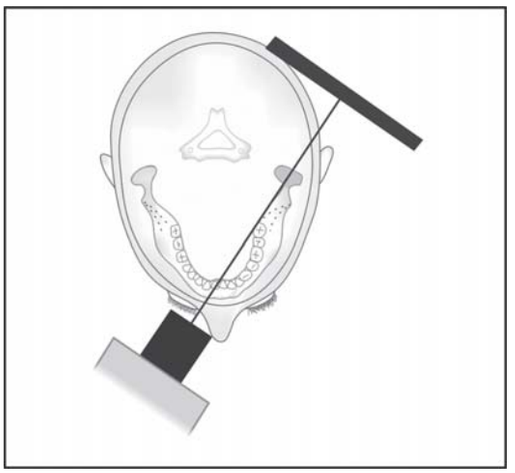


Fig. 12.16A: Transorbital projection, the central ray is oriented downward approximately 10° and laterally approximately 30° through the contralateral orbit, centered over the TMJ of interest

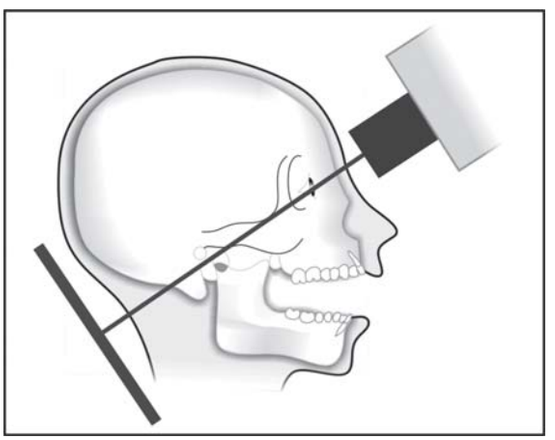


Fig. 12.16B: Transorbital projection, positioning from above, showing the cassette behind the condyle and X-ray beam aimed across the orbit

Fig. 12.16C: Transorbital view

4. Reverse Towne's (Figs 12.17 A and B)

Structures Shown

This view is primarily meant for viewing the condylar neck and head. High fractures of the condylar necks, intra capsular fractures of the TMJ, quality of articular surfaces, condylar hypoplasia or hypertrophy.

Film Position

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is placed vertically.

Position of Patient

The position of the patient is the same as that in PA mandible, that is,

The sagittal plane should be vertical and perpendicular to the film.

The film is adjusted so that the lips are centered to the film.

Only the patient's forehead and tip of the nose should touch the film.

The only difference being that the patient here is asked to keep his/her mouth wide open and the radiographic base line is at an angle of negative 30° to the film.

Central Ray

Is directed through the midsagittal plane at the level of the mandible, and is perpendicular to the film.

Exposure Parameters

kVp-65 mA-10 Seconds-2-3

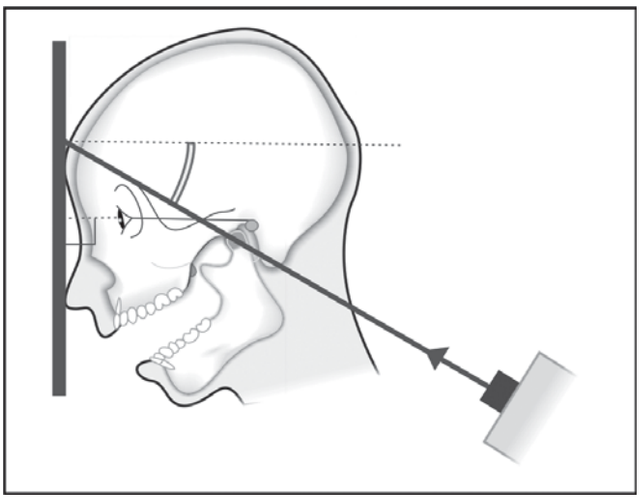


Fig. 12.17A: Diagram for the positioning of Reverse Towne's projection, the radiographic base line is perpendicular to the film and the X-ray is directed at 30° to the film

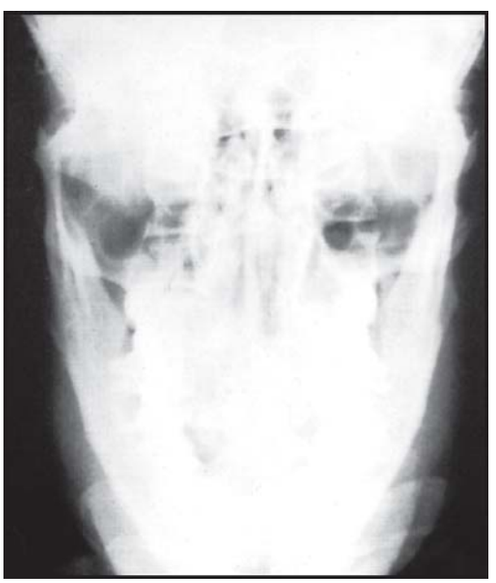


Fig. 12.17B: Reverse Towne's view

SKULL PROJECTION

1. Lateral Cephalogram (Figs 12.18A to C)

Structures Shown

This view is used to evaluate facial growth and development, trauma, disease and developmental anomalies.

This projection demonstrates the bones of the face, skull as well as the soft tissue profile of the face.

The soft tissue outline of the face is more readily seen on the resulting radiograph when a filter is used. A filter is placed at the X-ray source, or between the patient and the film, and serves to remove some of the X-rays that pass through the soft tissue of the face, thus enhancing the image of the soft tissue profile.

In oral surgery and prosthetics it is used to establish pretreatment and post treatment records.

Film Position

The cassette is placed perpendicular to the floor with the long axis of the cassette placed vertically. (FFD is the largest, 5 feet).

Position of Patient

The left side of the patient's head is positioned against the cassette.

The mid sagittal plane is perpendicular to the floor and parallel to the film/cassette.

The patient's head is stabilized with the help of the ear rods, nasion positioner and the orbital rod.

The patient is asked to keep the teeth in occlusion.

Central Ray

The central ray is directed perpendicular to the cassette through the porion.

The distance between the X-ray source and the midcoronal plane of the patient is 60 inches.

Exposure Parameters

kVp-84 mAs-13 Seconds-1.6

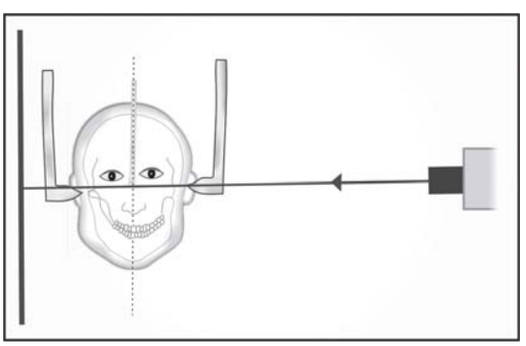


Fig. 12.18A: Lateral cephalogram, the film is parallel to the midsagittal plane and the X-ray beam is directed perpendicular to the film

Fig. 12.18B: Lateral skull radiograph (cephalometric technique). A cephalometric radiograph showing the relationship between the maxilla and the mandible in a patient with a class I occlusion, and demonstrating the soft tissue profile of the face. Note the broad radiopaque banding running vertically across the middle of the skull formed by part of the craniostat and also the circular ear-plugs

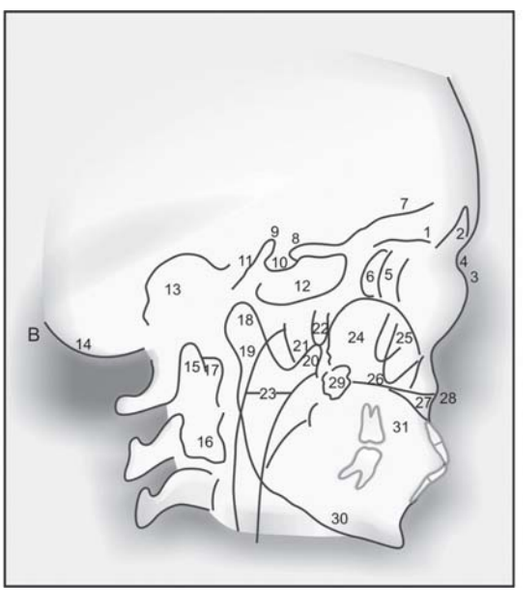


Fig. 12.18C: Labelled line diagram of lateral cephalogram, showing important landmarks 1. Roof of orbit (floor of anterior cranial fossa) 2. Frontal sinus, 3. Nasal bone, 4. Nasion, 5. Frontal process of zygoma (lateral orbital rim), 6. Ethmoid air cells, 7. Cerebral surface anterior cranial fossa, 8. Anterior clenoid process, 9. Posterior clenoid process 10. Floor of sella turcica, 11. Clivus, 12. Sphenoid sinus, 13. Mastoid air cells, 14. Floor of posterior cranial fossa, 15. Odontoid process, 16. Body of C2, 17. Anterior arch of C1, 18. Mandibular condyle, 19. Mandibular neck, 20. Coronoid process, 21. Pterygoid plate, 22. Pterygo-palatine fossa, 23. Nasopharyngeal soft tissue, 24. Maxillary antrum, 25. Zygomatic recess of maxillary antrum, 26. Hard palate, 27. Premaxilla, 28. Anterior nasal spine, 29. Unerupted maxillary third molar, 30. Body of ramus, 31. Maxilla

2. True Lateral (Figs 12.19A and B)

Structures Shown

Is used to survey the skull and facial bones for evidence of trauma, disease or developmental abnormality. This view reveals the nasopharyngeal soft tissues, paranasal sinuses and hard palate.

Conditions affecting the sella turcica, such as tumors of the pituitary gland in acromegaly.

Film Position

The film is held vertically against the patient's cheek and centered so that the entire skull is along with the facial skeleton, is seen on the resultant radiograph.

Position of Patient

The sagittal plane should be vertical and parallel to the film.

The film is adjusted so that the upper circumference of the skull is ½ inch below the upper border of the cassette.

The patient here is asked to keep his/her teeth in occlusion, and the occlusal plane should be parallel to the floor.

Central Ray

The central ray is directed perpendicular to the cassette and the midsagittal plane and towards the external auditory meatus.

The distance between the X-ray source and the midcoronal plane of the patient is 36 to 40 inches.

Exposure Parameters

kVp-65 mA-10 Seconds-0.5-2

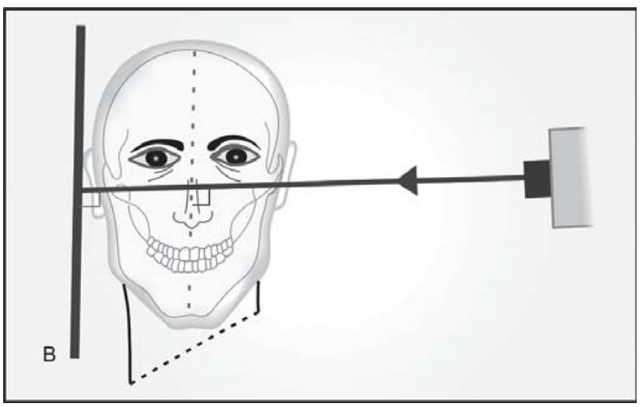


Fig. 12.19A: True lateral skull projection, the sagittal plane of the head is parallel to the film and the X-ray beam is horizontal and perpendicular to the sagittal plane and the film

Fig. 12.19B: True lateral view

3. PA Cephalogram (Figs 12.20A and B)

Structures Shown

Is used to survey the skull vault and primarily the facial bones for evidence of trauma, disease or developmental abnormality.

Fractures of the skull vault, investigation of frontal sinuses, conditions affecting the cranium (e.g. paget's disease, multiple myeloma, hyperparathyroidism), intra cranial calcifications.

Film Position

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

The sagittal plane should be vertical and perpendicular to the film.

The head is tipped downwards so that only the nose touches the film. The radiographic base line is at 10° with the film.

The film is adjusted so that the lips are centered to the film.

Central Ray

Is directed at right angles to the film through the midsagittal plane, centered at the level of the bridge of the nose.

Exposure Parameters

kVp-84 mA-13 Seconds-1.5

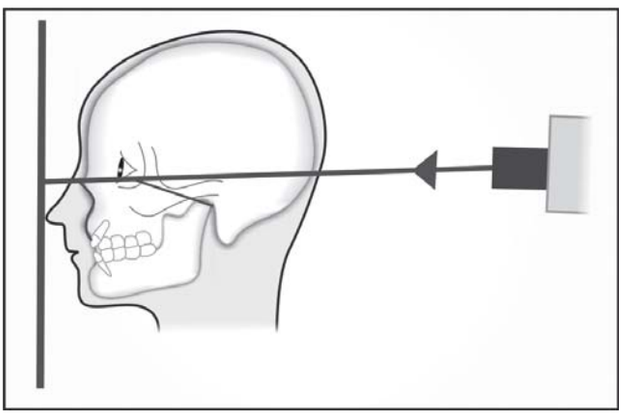


Fig. 12.20A: Diagram for the positioning of PA cephalogram

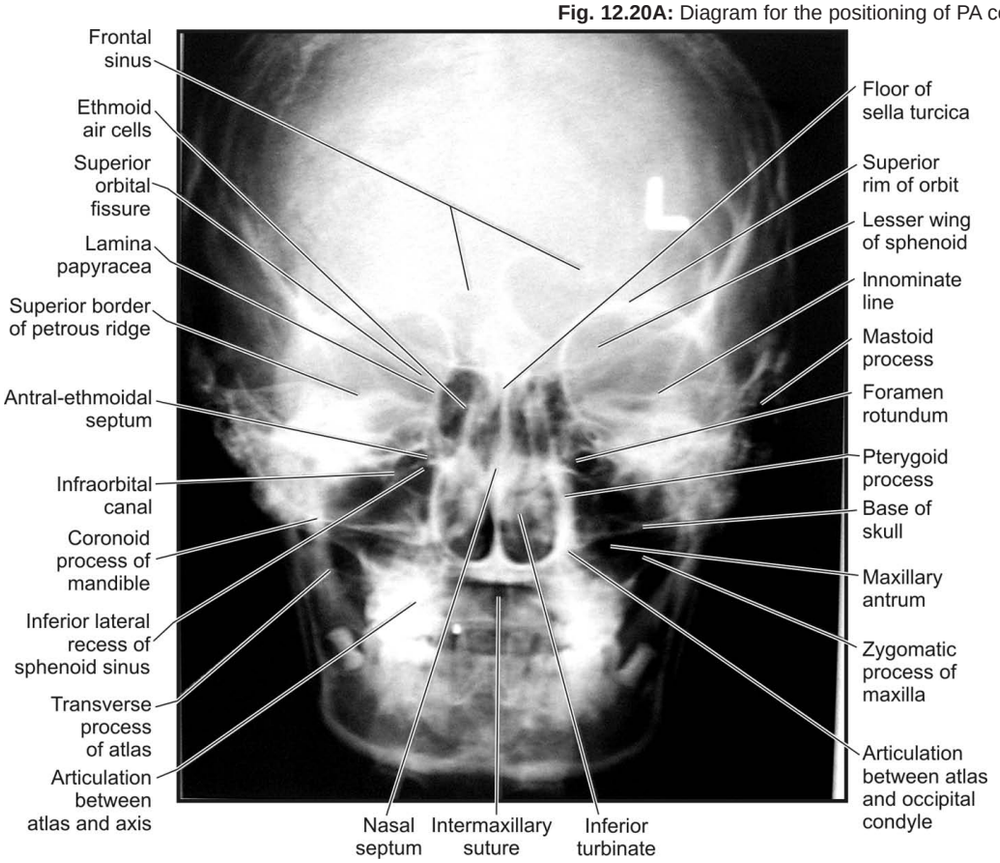


Fig. 12.20B: PA cephalometric view with anatomical landmarks identified

4. PA Skull (Figs 12.21A and B)

Structures Shown

Is used to survey the skull vault and primarily the facial bones for evidence of trauma, disease or developmental abnormality.

Fractures of the skull vault, investigation of frontal sinuses, conditions affecting the cranium (e.g. paget's disease, multiple myeloma, hyperparathyroidism), intra cranial calcifications.

Film Position

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

The sagittal plane should be verticle and perpendicular to the film.

The head is tipped downwards so that the forehead and nose touch the film. The radiographic base line is horizontal and perpendicular to the film.

The film is adjusted so that the lips are centered to the film.

Central Ray

Is directed at right angles to the film through the midsagittal plane through the occiput.

Exposure Parameters

kVp-65 mA-10 Seconds-2-3

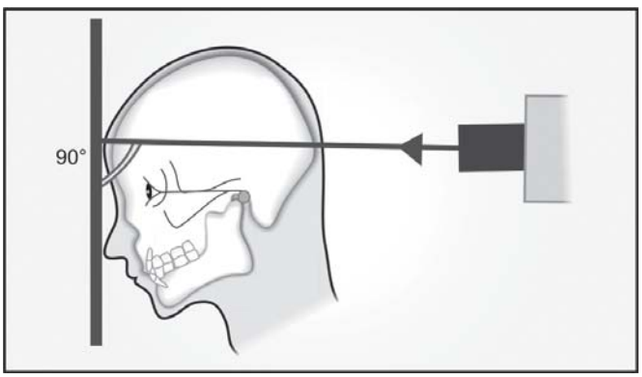


Fig. 12.21A: Diagram for the positioning of PA skull projection, the radiographic base line is horizontal to the film and the X-ray beam is perpendicular to the film

Fig. 12.21B: PA skull view

5. Towne's Projection (Figs 12.22A to C)

Structures Shown

It is primarily used to observe the occipital area of the skull. The necks of the condyloid process can also be viewed.

Film Position

The cassette is placed perpendicular to the floor in a cassette holding device. The long-axis of the cassette is positioned vertically.

Position of Patient

This is an anteroposterior view, with the back of the patient's head touching the film. The canthomeatal line is perpendicular to the film.

Central Ray

Is directed at 30° to the canthomeatal line and passes through it at a point between the external auditory canals.

Exposure Parameters

kVp-65 mA-10 Seconds-2-3

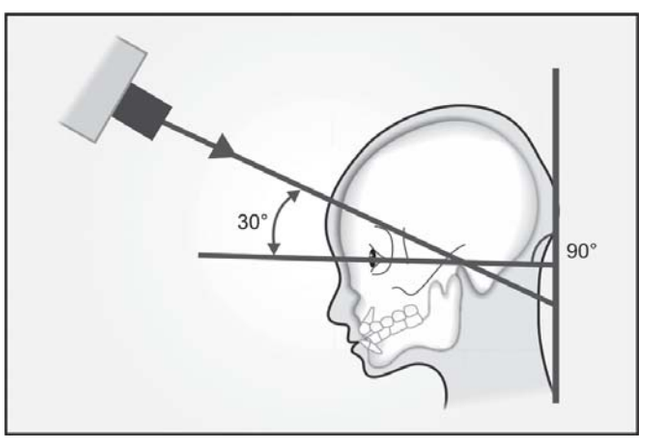


Fig. 12.22A: Diagram for the positioning for Towne's projection, showing back of head of the patient touching the cassette and the central ray at an angle of 30° to the canthomeatal line

Fig. 12.22B: Towne's view

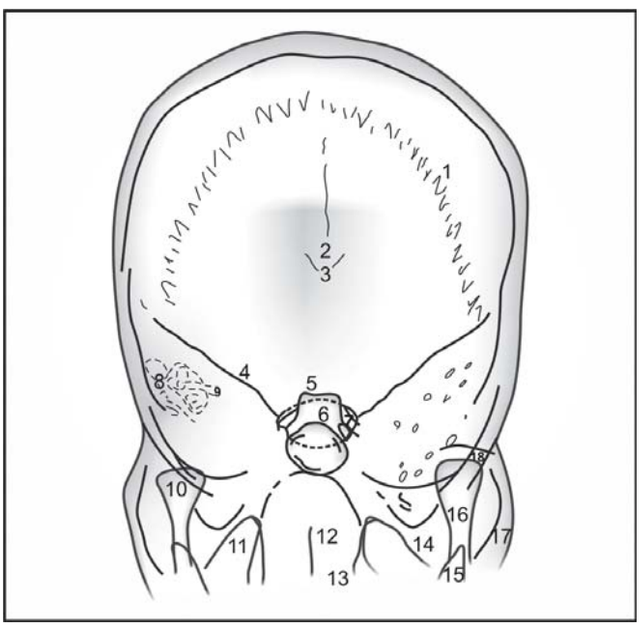


Fig. 12.22C: Anatomical landmarks seen on Towne's view
1. lambdoid suture; 2. internal occipital crest; 3. occiput; 4. petrous ridge of the temporal bone; 5. posterior clinoid process; 6. dorsum sellae; 7. foramen magnum; 8. mastoid air cells; 9. internal auditory canal; 10. head of the mandibular condyle; 11. maxillary antrum; 12. nasal septum; 13. mesial wall of the maxillary antrum; 14. roof and wall of the maxillary antrum; 15. neck of the mandibular condyle; 16. coronoid process of the mandible; 17. zygomatic arch; 18. temporomandibular joint space

Table 12.1: Radiograph investigations to examine the antra

Radiographic view	*Area of the antrum shown*
Periapical	Floor, base of the antral cavity, relationship with upper posterior teeth.
OPG	Floor, posterior wall, base of the antral cavity, relationship with the posterior teeth, allows comparison with both sides.
Standard occipitomental	Main antral cavity, lateral wall, roof or upper border, medial wall, allows comparison of both sides.
Posterior topographic occlusal view	Floor, lower half of the antral cavity, relationship with upper posterior teeth.
True lateral skull	Main antral cavity, posterior wall, anterior wall (in this view the antral shadows superimpose each other).
Linear tomography in coronal or sagittal plane	Main antral cavity, floor, anterior wall, lateral wall, posterior wall medial wall, roof or upper border, allows comparison of both sides.
Computed tomography (CT)	Main antral cavity, floor, all walls, roof or upper border, surrounding structures, allows comparison of both sides, images hard and soft structures.

Table 12.2: Radiograph investigations to examine the various paranasal air sinuses

Air sinus	*Radiographic view*
Frontal	Standard occipitomental P A skull True lateral skull Tomography CT
Sphenoidal	Standard occipitomental (with patient's mouth open) True lateral skull Submentovertex (SMV) Tomography CT
Ethmoidal	Standard occipitomental 30° occipitomental True lateral skull PA skull Tomography CT

Table 12.3: Radiograph investigations to examine mandibular fracture sites

Fracture site	*Radiographic view*
Angle	OPG Lateral oblique
Condylar neck	OPG Lateral oblique Reverse Towne's Transorbital
Body	OPG Lateral oblique P A mandible Periapical of involved teeth. Lower true occlusal
Canine region	OPG Lateral oblique Periapical of involved teeth True lateral skull
Symphysis	Lower true occlusal Lower anterior topographic occlusal
Ramus	OPG Lateral oblique P A mandible
Coronoid process	OPG Lateral oblique Standard occipitomental

Table 12.4: Radiograph investigations to examine fractures of the middle third

Fracture type/site	*Radiographic view*
Dento-alveolar	Periapical Upper true occlusal Upper topographic occlusal
Le Fort I	Standard occipitomental 30° Occipitomental True lateral skull (brow up)
Le Fort II	Standard occipitomental 30° occipitomental True lateral skull (brow up)
Le Fort III	Standard occipitomental 30° occipitomental True lateral skull (brow up) Coronal section tomography CT
Zygomatic complex	Standard occipitomental 30° occipitomental Submentovertex (SMV) Jug handle view
Naso-ethmoidal complex	True lateral skull (brow up) Standard occipitomental 30° occipitomental Soft tissue lateral view of the nose P A Caldwell CT
Orbit	Standard occipitomental True lateral (brow-up) P A Caldwell Coronal section tomography CT

Table 12.5: Radiograph investigations to examine fractures of the cranium, cervical spine and intracranial injuries

Fracture type/site	*Radiographic view*
Skull vault	PA skull True lateral AP skull Tangential views of trauma site
Cranial base	True lateral (brow up) Tomography Submentovertex (SMV) CT
Cervical spine	True lateral of the neck AP neck Tomography CT
Intracranial injuries	CT

Table 12.6: Radiograph investigations to examine different aspects of the TMJ

Radigraphic view	*Area of the joint seen*
Transcranial	Lateral aspect of glenoid fossa articular eminence joint space condylar head
Transpharyngeal	Lateral aspect of condylar head and neck articular surface
OPG	Lateral view of both condylar heads lying within the focal trough.
Reverse Towne's	Posterior view of both condylar heads and necks
Transorbital	Anterior view of condylar head and neck articular surface
Tomography	All aspects of glenoid fossa articular eminence joint space condylar head

Table 12.7: Radiographic projections for the parotid and submandibular glands

Salivary gland	*Radiographic view*
Parotid	OPG Lateral oblique Rotated PA or AP Intraoral view of the cheek
Submandibular	OPG Lateral oblique Lower true occlusal view Lower posterior topographic view True lateral skull (with the tongue depressed)

BIBLIOGRAPHY

1. Goaz PW, White SC. Extraoral examination in oral radiology. Principles and Interpretation, 3rd ed. St Louis, CV Mosby, 1994; 299-313.
2. Johnson ON, McNally MA, Essay CE. The extra oral radiography in essentials of dental radiography for dental assistants and hygienists, 6th ed. Norwalk, Appleton and Lange, 1999;443-49.
3. Laskin DM. Oral and Maxillofacial Surgery, C.V. Mosby Co.Vol I 1980; 413.
4. Lincon R. Mason-Hing. Fundamentals of Dental Radiology, Lea and Febiger 1979; 113.
5. Mason-Hing LR. Occlusal and extra oral radiography. Fundamentals of Dental Radiography, 3rd ed, Philadelphia, WB Saunders, 1993; 144-54.
6. Richard CO' Brien. Dental Radiography: An Introduction for Dental Hygienists and Assistants, WB Saunders Co. 3rd ed. 1977.
7. Smith NJD. Dental Radiography, Blackwell Scientific Publications, 1980;68.

13

Panoramic Radiography

Panoramic radiography, also known as pantomography or rotational radiography, is a radiographic procedure that produces a single tomographic image of facial structures including both maxillary and mandibular arches and their supporting structures.

There is greater ease and less time taken to produce a panoramic radiograph as compared to full mouth intraoral periapical radiographs, and the additional advantage is that there is visualization of areas of the Body of the Mandible, Ramus, TM joint, and the Maxillary Sinus.

Panoramic radiography is of two types:

- Intraoral source of panoramic radiography - Status –X (Fig. 13.1)
- Extraoral source of panoramic radiography – OPG (Fig. 13.2)

In panoramic radiography, the film and X-ray tube head move around the patient. The X-ray tube moves around the patient's head in one direction while the film rotates in the opposite direction. The patient may be seated or standing in a stationary position. The movement of the tube head and the film produces an image through the process known as tomography. (This is a curvilinear variant of conventional tomography, and is also based on the principle of the reciprocal movement of an X-ray source and an image receptor around a central point or plane, called the image layer.) In panoramic radiography the image confirms to the shape of the dental arches.

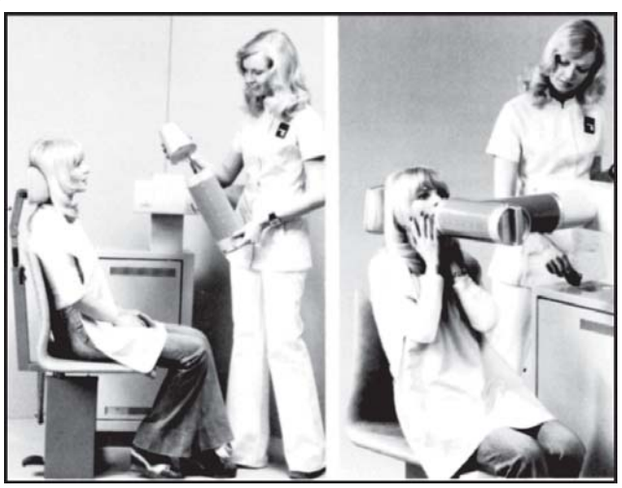


Fig. 13.1: The status X-ray intraoral X-ray source machine (Courtesy of Siemens Corporation, Iselin, New Jersey)

Principle

If the film moves at a speed that follows the moving projection of a certain point, this point will always be projected on the same spot on the film and will not appear unsharp.

In the OPG the film is attached to a rotating system and moves in the same direction as the beam. The film is given the correct speed by appossing this movement with a contrary movement relative to the beam.

The Focal Trough or Image Layer (Fig. 13.3)

Is defined as that zone which contains those object points which are depicted with optimum resolution in other words it is a three dimensional curved zone in which structures are clearly demonstrated on a panoramic radiograph.

In the OPG the arches should be placed within the image layer.

The image layer thickness, depends upon the effective projection radius and the width of the beam. The size and shape of the focal trough varies according to the manufacturer. The closer the rotation center to the teeth, narrower the focal trough. In most machines the focal trough is narrow in the anterior region and wide in the posterior region.

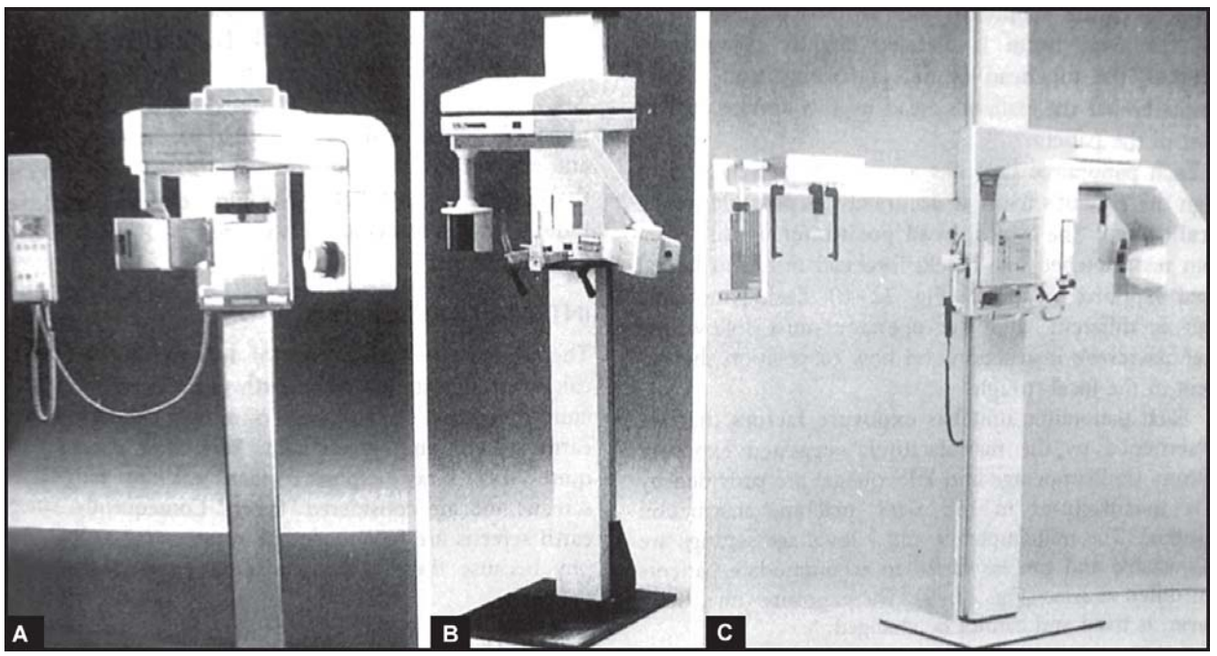


Fig. 13.2: A. The orthopantomograph 10E extraoral machine. **B.** The GX-Pan extraoral X-ray machine. **C.** The cranex 3 cep extraoral X-ray machine

Since the jaws are not circular, a variety of movement patterns for the beam have been developed.

Rotation Center (Fig. 13.4)

In panoramic radiography, the film or cassette carrier and the tube head are connected and rotate simultaneously around a patient during exposure. The pivotal point or axis, around

Fig. 13.3: Focal trough. The closer to the center of the trough (dark zone) an anatomic structure is positioned, the more clearly it is imaged on the resulting radiograph

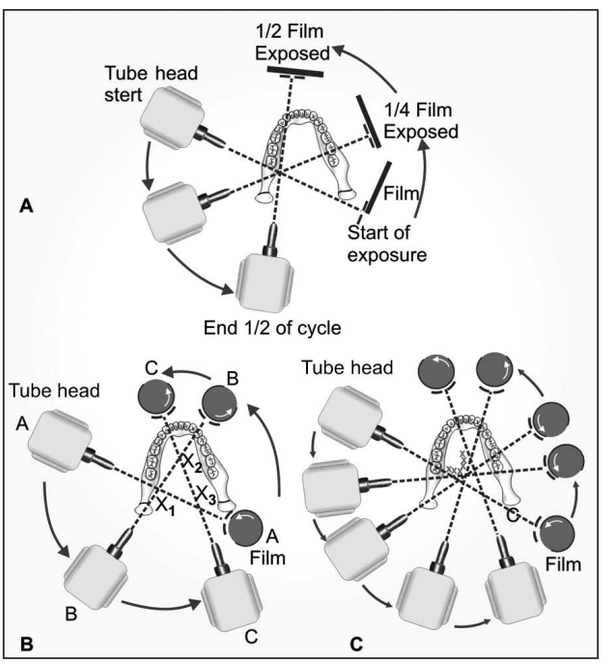


Fig. 13.4: Types of panoramic X-ray machines. **A.** Double center of rotation, machines have two rotational centers, one for the right and one for the left side of the jaws. **B.** Triple center rotation machines have three centers of rotation and create an uninterrupted radiographic image of the jaws. **C.** Moving center rotation machines rotate around a continuously moving center that is similar to the arches, creating an uninterrupted image of the jaws

which the cassette carrier and X-ray tube head rotate is termed a rotational center.

- The earlier techniques used stationary rotation center of the beam, placed at one side of the jaws, projecting the other side of the jaws. The rotation center is then shifted symmetrically by moving the patient. This projection technique produced the – "Split Image"
- Single Center of Rotation—Dr. Paatero applied the principles of curved surface tomography, to relate to circular tomography, e.g. The Rotagraph Machine.
- Two Centers of Rotation—This follows the principle that, the individual left and right sides of the arc formed by the teeth and jaws closely form a part of a circle. It was suggested that the center of rotation be positioned some what anteriorly to the location of the third molar opposite the side being examined. This double rotational principle was used in the Panorex machine.
- Three Centers of Rotation—Three centers of rotation system divided the arc of the jaws into three areas:
  - A condyle to first bicuspid posterior segment
  - A cuspid to cuspid anterior segment
  - A contralateral-posterior segment.

These three curved segments have three different centers; two are bilaterally situated slightly postero-lateral to the third molars, and the third is situated in the midline posterior to the incisors.

The X-ray beam can be shifted from one center to the other without any interruption and a continuous image can be made from condyle to condyle, e.g. The orthopantomograph, panoram, panora.

- Moving Rotational Centers—Systems described so far have rotation centers or X-ray beams which were positioned at one or more fixed locations during exposure. Pantomography is also achieved if the beam rotates around a fixed point or center.

All these machines employ a moving rotational center that traces a path of the shape of an eclipse. Therefore, this system is also called "Ellipso-pantomography".

In all cases, the center of rotation changes as the film and tube head rotate around the patient. The rotational change allows the image layer to conform to the elliptical shape of the dental arches. The location and number of rotational centers influence the size and shape of the focal trough.

Equipment

- Panoramic X-ray unit—there are a number of units available, which differ in the number of rotational centers, the size and shape of the focal trough, and type of film transport mechanism. The main components of the panoramic unit include (Fig. 13.5):

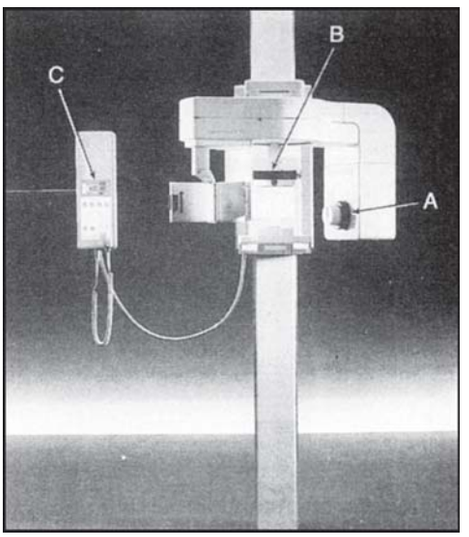


Fig. 13.5: The main components of the panoramic unit include: **A.** The X-ray tube head. **B.** The head positioner. **C.** The exposure controls

  - X-ray tube head: This is similar to that of the intra-oral machine except that:
    - the collimator used is a lead plate with a slit, and the X-ray beam thus emerges through the collimator as a narrow band. This beam passes through the patient and then exposes the film through another vertical slit in the cassette carrier (the metal holder that supports the cassette). This narrow beam gives minimal exposure to the patient. (Fig. 13.6).
    - the vertical angulation of the panoramic tube head is not varied. It is in a fixed position so that the beam is directed slightly upwards.

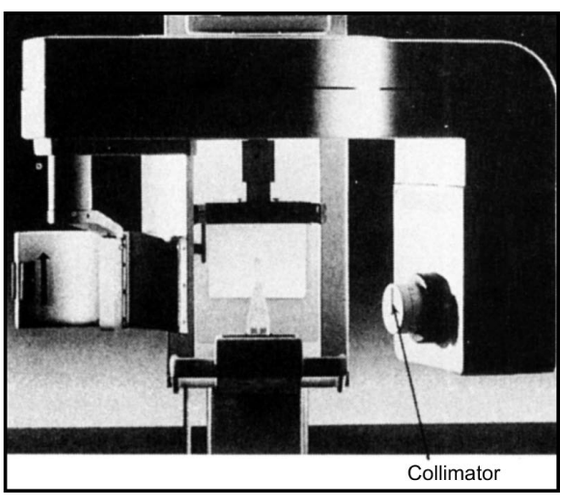


Fig. 13.6: The collimator on a panoramic unit has a narrow slit opening

- ➢ the panoramic tube head always rotates behind the patients head as the film rotates in front of the patient.

– *Head positioner*: Consists of a chin rest, notched bite-block, forehead rest and lateral head support guides (Fig. 13.7).
– *Exposure controls*: The milliamperage and kilovoltage settings are adjustable and can be varied to accommodate patients of different sizes. The exposure time is fixed and cannot be changed (Fig. 13.8).

Exposure Parameters

kVp- 76	mA-15	Seconds- 15	Dose to the patient- 0.103 mr +/- 0.008
kVp- 80	mA-15	Seconds- 15	Dose to the Patient- 0.116 mr +/- 0.008

[In the case of full mouth examination with 14 intraoral films with a machine having;

kVp- 60	mA-07-10	Seconds- 0.35/ film	Dose to the patient- 0.712 mr +/- 0.052]

- Screen film.
- Intensifying screens.
- Cassette (Fig. 13.9): this may be rigid or flexible, curved or straight, depending on the panoramic unit.

PROCEDURE

1. Explain the procedure to the patient.

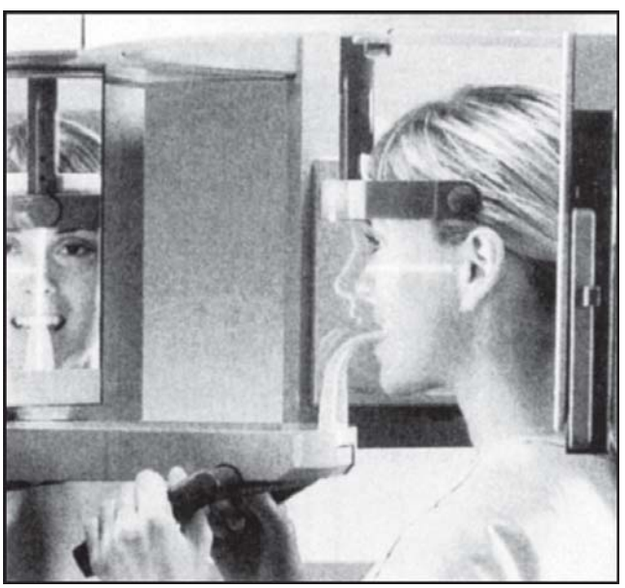


Fig. 13.7: The head positioner (notched bite block, forehead rest and lateral head supports) is used to align the patient's teeth in the focal trough

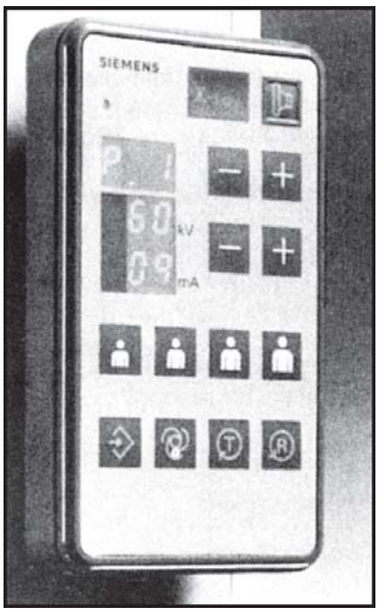


Fig. 13.8: An example of exposure control switch for a panoramic unit

2. Make the patient wear a lead apron without a thyroid collar, and remove all objects from the head which will interfere with film exposure. Also have the patient remove jacket or bulky sweater, this allows more room between the bottom of the cassette holder and the patient's shoulder.

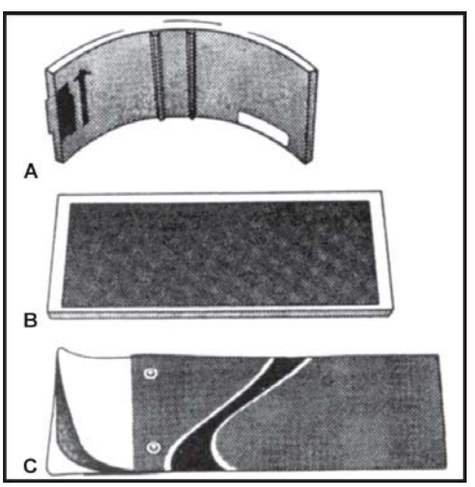


Fig. 13.9: Film cassettes: **A.** and **B.** are rigid cassettes, here the intensifying screens are attached to the inside cover and base of the cassette. When the panoramic film is placed in the cassette, it lies in between the screens. **C.** shows a flexible cassette that has an opening at one end creating a pouch. The panoramic film is placed between two removable, flexible intensifying screens which are then slid into the pouch

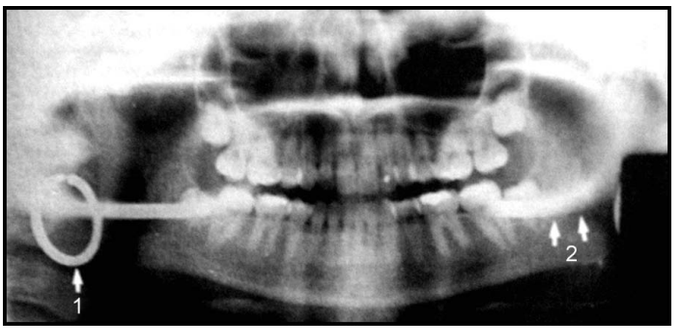


Fig. 13.10A: Ghost images **A.** Large hoop earrings (1) and ghost images (2). The ghost image of the earring apears on the opposite side of the film and is enlarged and laterally distorted

3. Load the panoramic film in the dark room, and cover the bite block with a diposable plastic cover slip (Fig. 13.19)
4. Set the exposure factors and adjust the height of the machine to accommodate the patient.
5. Instruct the patient to sit or stand with the back straight and erect, and ask him to bite on the plastic bite block. The upper and the lower front teeth must be placed in an end-to-end position in the groove of the bite block.
6. The midsagittal plane should be perpendicular to the floor and aligned with the vertical center of the chin rest, and the Frankfurt plane should be parallel to the floor, thus obtaining the correct position for the occlusal plane. (the patient's head is tilted downwards so that the tragus ala line is 5° down and forward.) If the patient has a low palatal vault, increase the occlusal plane angulation slightly, if the patient has a high palatal vault decrease the occlusal plane slightly. The indicator lights in the machine help as a guide and the patients head should be immobilized by the head band.
7. Center the lower border of the mandible on the chin rest and is equidistant from each side.
8. Instruct the patient to position the tongue on the palate and ask him to remain still while the machine is rotating during exposure. Also explain that the cassette holder will not strike him, although it may gently rub his ear and head at the limits of the excursion.
9. After the exposure is complete the film is subjected to routine processing.

Common Errors

1. *Ghost images*: This is a radiopaque artifact seen on a panoramic film that is produced when a radiodense object is penetrated twice by the X-ray beam (Figs 13.10A to E).
   The characteristics of a ghost image are:
   i. A ghost image resembles it's real counterpart and has the same morphology.
   ii. It is found on the opposite side of the film from it's real counterpart.

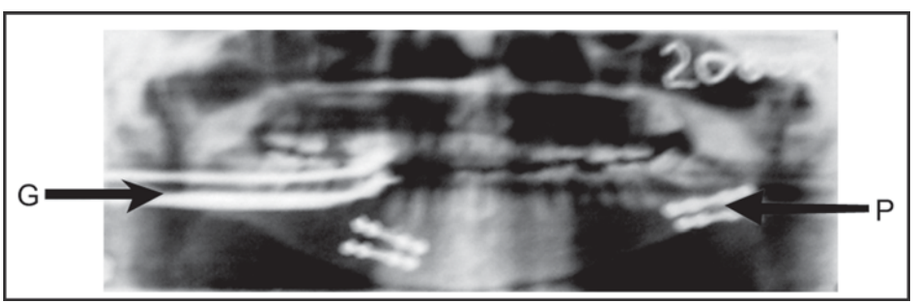


Fig. 13.10B: Ghost images of metal plates
P – Metal plates (Real image)
G – Metal plates (Ghost images)

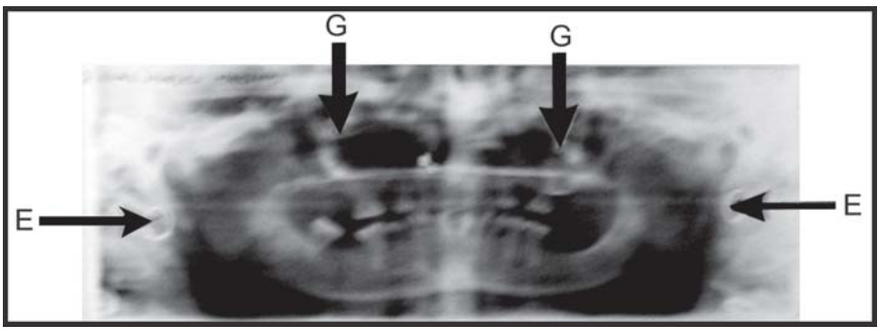


Fig. 13.10C: Ghost images of earrings

E – Real images of earrings
G – Ghost images of earrings

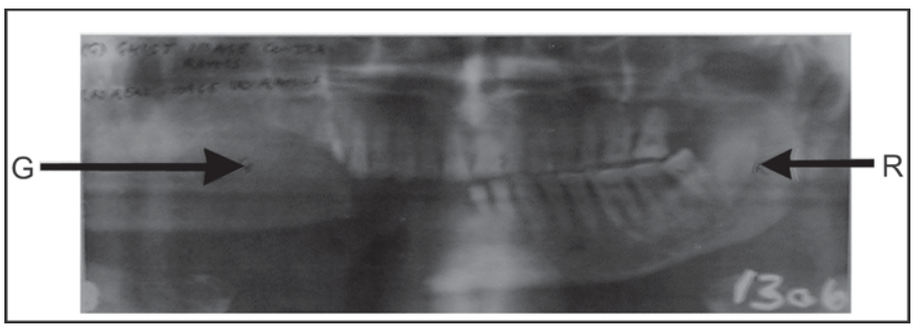


Fig. 13.10D: Ghost image of contra ramus

R – Real images of ramus
G – Ghost images contra ramus

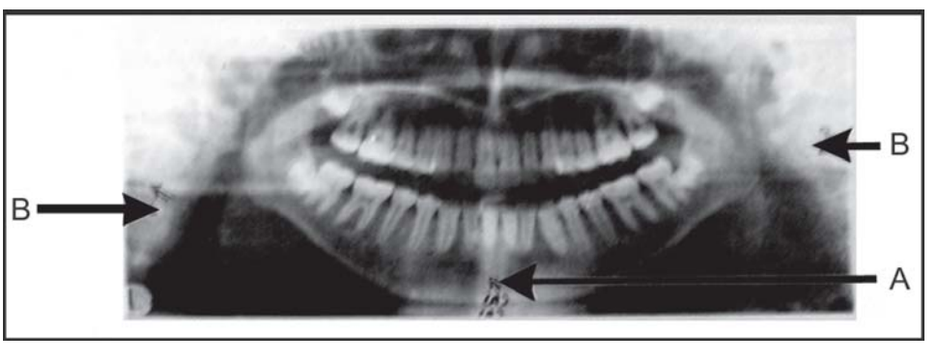


Fig. 13.10E: Ghost image of spine

A – Ghost image of spine
B – Double real image of spine

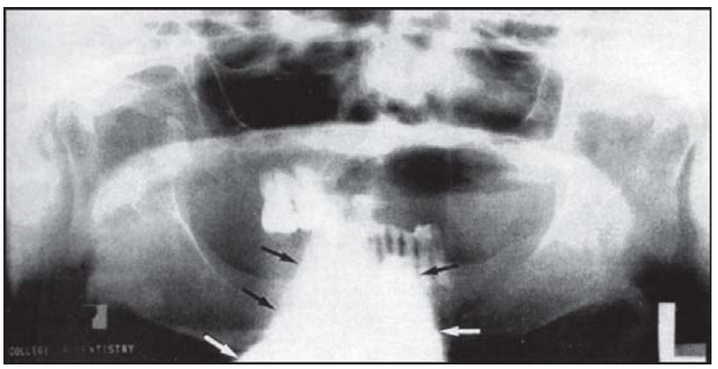


Fig. 13.11: Lead apron artifact appears as a large cone shaped radiopacity obscuring the mandible

iii. It appears indistinct, the vertical components are more blurred than the horizontal components of a ghost image.
iv. The ghost image is always larger than the real counterpart, the vertical component is severly magnified, whereas the horizontal component is not as severly magnified.
v. It is usually placed higher than its actual counterpart.

- Anatomical structures which are most often ghosted are:
  i. Hyoid bone
  ii. Cervical spine
  iii. Inferior border of the mandible
  iv. Posterior border of the mandible
  v. The meati
  vi. The turbinates.
- Non-anatomical structures which are often ghosted are:
  i. Chin rest
  ii. (R) or (L) Markers of the machine
  iii. Neck chains
  iv. Napkin chains
  v. Earrings
  vi. Shoulder straps of protective aprons.

2. *Lead apron artifact* (Fig. 13.11)
3. *Patient positioning errors*:
   i. Positioning of the lips and teeth:

If the lips are not closed on the bite block, a dark radiolucent shadow obscures the anterior teeth.

If the tongue is not in contact with the palate, a dark radiolucent shadow obscures the apices of the maxillary teeth (Fig. 13.12).

ii. Positioning of the Frankfurt plane
   a. *Upward*: (Fig. 13.13)
      If the patient's chin is positioned too high or tipped up (i.e. the chin is too far forward while the forehead is titled towards the back):
      - The hard palate and the floor of the nasal cavity appear superimposed over the roots of the maxillary teeth.

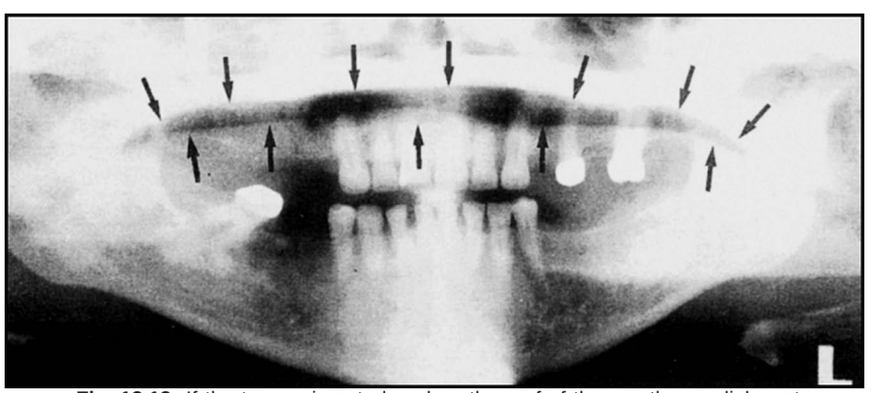


Fig. 13.12: If the tongue is not placed on the roof of the mouth, a radiolucent shadow will be superimposed over the apices of the maxillary teeth

Fig. 13.13: The chin and the occlusal plane are rotated upward, resulting in the overlapping of the images of the teeth and an opaque shadow (the hard palate) obscuring the roots of the maxillary teeth

- Loss of density in the middle of the radiograph, usually characterized by an hour glass shape.
- There is a loss of detail in the maxillary incisor region, magnification.
- The maxillary incisors appear blurred and magnified.
- Loss of one or both condyles at the side of the film.
- A 'reverse smile line' is seen on the radiograph (flattening of the occlusal plane)

b. *Downward*: (Fig. 13.14)
Ala-tragus line greater than 5° downward,the patient's chin is positioned too low or is tipped down (i.e. chin positioned back and the forehead is positioned forward);

- The mandibular incisors appear blurred.
- There is a loss of detail in the anterior apical region. The apices of the lower incisors are out of focus and blurred.
- The condyles may not be visible, as they may be cut off at the top of the radiograph.
- Shadow of the hyoid bone is superimposed on the anterior aspect of the mandible.
- Premolars are severly overlapped.
- An 'exaggerated smile line' is seen on the radiograph (severe curvature of the occlusal plane).

iii. Positioning of the teeth

a. *Anterior to the focal trough*: (Fig. 13.15)
Patient's head is positioned too far forward.

- If the anterior teeth are not positioned in the groove of the bite block, the teeth appear blurred
- If the teeth are positioned too far forward on the bite block, the anterior teeth appear 'skinny' and out of focus (Blurred and narrow)
- Spine is superimposed on the ramus areas
- Premolars are severely overlapped.

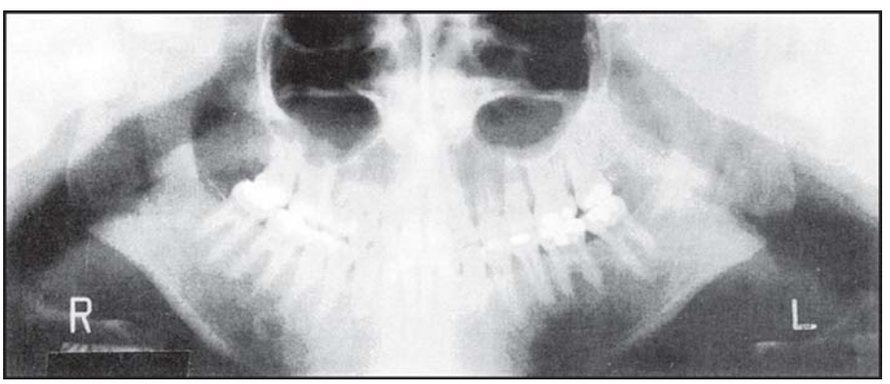


Fig. 13.14: An exaggerated smile seen on a panoramic film when the patient's chin is tipped down

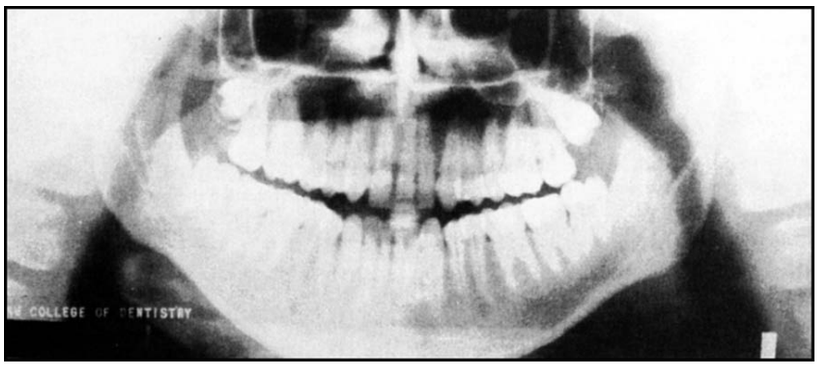


Fig. 13.15: The anterior teeth appear narrow and blurred on a panoramic film when the patient is positioned too far forward on the bite block

b. *Posterior to the focal trough*: (Fig. 13.16)
Patient's head is positioned too far back
- If the anterior teeth are not positioned in the groove of the bite block, the teeth appear blurred
- If the teeth are positioned too far back on the bite block, the anterior teeth appear 'fat' and out of focus (blurred and wide)
- Excessive ghosting of mandible and spine.

iv. *Positioning of the midsagittal plane*: (Fig. 13.17)
If the patient's head is not centered, the ramus and the posterior teeth appear unequally magnified. The side farthest from the film appears magnified and the side closest to the film appears smaller.
a. Patient's head is tilted to one side.
- The side tilted towards the X-ray tube is enlarged.
- One condyle appears larger than the opposite one, the neck also appears longer on the larger side.
- Image appears to be tilted, one angle of the mandible is higher than the other.

b. Patient's head is twisted to one side causing the mandible to fall outside the image layer, (one side is in front of the image layer while the other side is behind the image layer)
- Teeth on one side of the midline appear wide and have severe overlapping of contacts, whereas the teeth on the other side appear very narrow

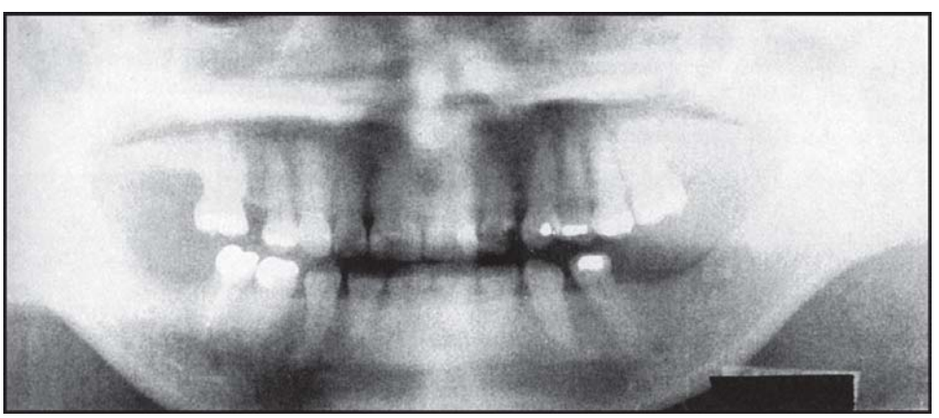


Fig. 13.16: The anterior teeth appear widened and blurred on a panoramic film when the patient is positioned too far back on the bite block

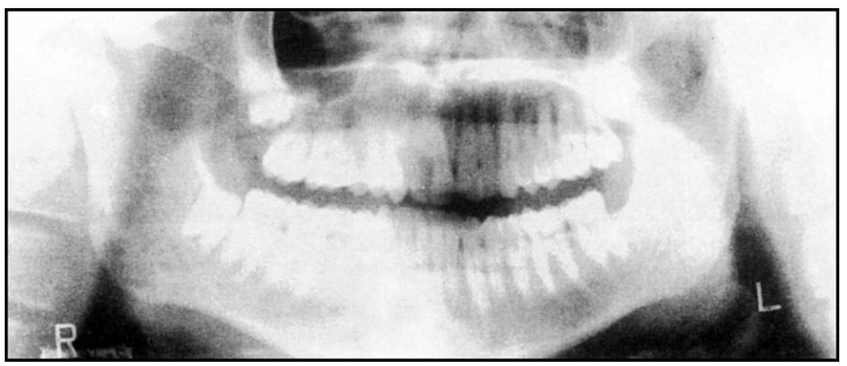


Fig. 13.17: The patient's posterior teeth and ramus appear to be magnified on the panoramic film when the head is not centered

- Ramus on one side is much wider than the other side
- Condyles differ in size.

c. Whole head is off center position (patient biting the block off center with lateral incisors or cuspids)
- The molar teeth and the mandibular ramus are magnified on the side farther from the film
- Anterior teeth are blurred with overlapping.

v. *Positioning of the spine* (Fig. 13.18)
If the patient is not sitting or standing with a straight spine, the cervical spine appears as a pyramid shaped radiopacity in the center of the film and obscures diagnostic information.

vi. *Patient's shoulder touching the cassette during exposure*
This will slow the cassette rotation, resulting in prolonged exposure or completely stop the film movement.
- Produces a dense black band, which is the area of overexposure or a dense black edge may be seen at the end of the radiographic image, due to eventual stoppage of rotation.

vii. *Position of patient's tongue during exposure* (Fig. 13.12)
If the tongue is not fully placed against the roof of the mouth.
- A dark shadow appears in the maxilla below the palate, and the apices of the maxillary incisors are obscured.

viii. *Distortion due to patient movement*

a. Movement in the same direction as the beam.
- There is prolonged exposure of the same area, with increase in horizontal dimension of the image.

b. Movement in the opposite direction as the beam.
- The horizontal dimension of the image in the region is decreased.

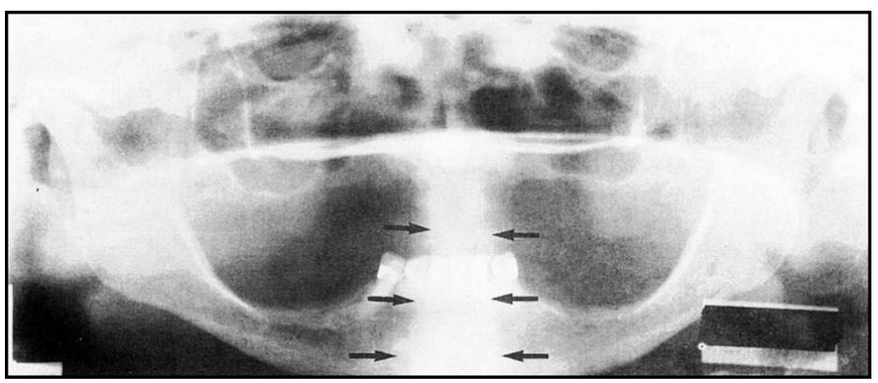


Fig. 13.18: If the patient is not standing erect, superimposition of the cervical spine may be seen on the center of the panoramic film

c. Sudden jerky movement in the same direction as the beam.
   - The area may be portrayed twice.

d. Sudden jerky movement in the direction opposite the beam movement.
   - A part of the object may be missing in the image.

e. If the patient moves up or down during exposure.
   - Indentation in the lower border of the mandible (mimicing a fracture)
   - Blurring and unsharpness.

4. *Cassette positioning errors*:

i. Patient's shoulders touching the cassette during the movement in the exposure cycle.
This may happen if the patient has a short neck and well developed shoulders.
   - Alternating vertical dark and light bands appear on the radiograph due to improper movement of the slit in the cassette holder or the tube head-cassette holder assembly around the patient's head.

ii. Cassette placed too high.
   - Lower border of the mandible is cut off.

iii. Cassette placed too low.
   - Diagnostic information in the maxilla will be cut off.

iv. Two exposures on a single film.
Undiagnostic radiograph, with unnecessary exposure to the patient.

v. Cassette placed backwards.
   - This is common in panorex the X-rays must penetrate the metal latch, which will present as a radiopaque broad horizontal line through the middle of the radiograph.

Clinical Indications

1. As a substitute for full mouth intraoral periapical radiographs.
2. For evaluation of tooth development for children, the mixed dentition and also the aged.
3. To assist and assess the patient for and during orthodontic treatment.
4. To establish the site and size of lesions such as cysts, tumors and developmental anomalies in the body and rami of the mandible.
5. Prior to any surgical procedures such as extraction of impacted teeth, enucleation of a cyst, etc.
6. For detection of fractures of the middle third and the mandible after facial trauma.
7. For follow-up of treatment, progress of pathology or postoperative bony healing.
8. Investigation of TM joint dysfunction.
9. To study the antrum, especially to study the floor, posterior and anterior walls of the antrum.
10. Periodontal disease- as an overall view of the alveolar bone levels.
11. Assessment for underlying bone disease before constructing complete or partial dentures.
12. Evaluation of developmental anomalies.
13. Evaluation of the vertical height of the alveolar bone before inserting osseo-integrated implants.

Advantages

1. Simple procedure requiring very little patient compliance.
2. Convenient for the patient.
3. Useful in patients with trismus and gagging problems.
4. Time required is minimal compared to a full mouth intraoral periapical radiographs.
5. That portion of the maxilla and the mandible lying within the focal trough can be visualized on a single film.
6. The patient dose is relatively low.
7. Panoramic radiographs taken for diagnostic purpose are valuable visual aid in patient education.
8. A broad anatomic region is imaged. In addition to the teeth and the supporting structures, the entire maxillary region and the entire mandible extending distally up to the TM joint is visualized. Also seen in the same plate are the pharyngeal air spaces, hyoid bone and the styloid process.
9. The anatomical structures are most identifiable and the teeth are oriented in their correct relationship to the adjacent structures and to each other.
10. It allows for the assessment of the presence and position of unerupted teeth in orthodontic treatment.
11. It demonstrates periodontal disease in a general way. Manifesting a generalized bone loss.
12. All the parameters are standardized and repetitive images can be taken, on recall visits for comparative and research purposes.
13. Useful for mass screening.
14. This view helps in localization of objects/pathology in conjunction with a topographic occlusal view or an intraoral periapical radiograph.
15. The radiation dose (effective dose equivalent) of app. 0.08 mSv is about one-third of the dose from a full mouth survey of intraoral films.

Disadvantages or Limitations

1. Areas of diagnostic interest outside the focal trough may be poorly visualized. For e.g. swelling on the palate, floor of the mouth.

2. Comparatively this radiograph is of a poor diagnostic quality, in terms of magnification, geometric distortion, poor definition and loss of detail.
3. There is an overlapping of the teeth in the bicuspid area of the maxilla and the mandible.
4. In cases of pronounced inclination, the anterior teeth are poorly registered.
5. The density of the spine, especially in short necked people can cause lack of clarity in the central portion of the film.
6. Number of radiopaque and radiolucent areas may be present due to the superimposition of real/double or ghost images and because of soft tissue shadows and air spaces.
7. Due to prescribed rotation, patient with facial asymmetry or patients who do not conform to the rotation curvature, cannot be X-rayed with any degree of satisfaction.
8. If the patient positioning is improper, the amount of vertical and horizontal distortion will vary from one part of the film to another part of the film.
9. The ease and convenience of obtaining an OPG may encourage careless evaluation of a patient's specific radiographic needs.
10. Artifacts are easily misinterpreted and are more commonly seen, e.g. nose ring as a periapical radiopaque lesion, earring as a calcification in the maxillary sinus.
11. OPG shows an oblique, rather than true lateral view of the condylar heads and hence the joint space cannot be accurately assessed.
12. Some patients donot conform to the shape of the focal trough and some structures will be out of focus.
13. The cost of the machine is very high.

Interpreting the Panoramic Image

Normal landmarks seen on the panoramic radiograph (Fig. 13.19A)

The normal anatomical shadows that are evident on the panoramic radiographs vary from one machine to another, but generally they may be subdivided into:

1. Real or actual shadows; of structures in or close to the focal trough.
   a. Hard tissue shadows
      - Teeth
      - Mandible
      - Maxilla, including the floor, anterior and posterior walls of the antra
      - Hard palate
      - Zygomatic arches
      - Styloid process
      - Hyoid bone
      - Nasal septum and conchae
      - Orbital rim
      - Base of skull

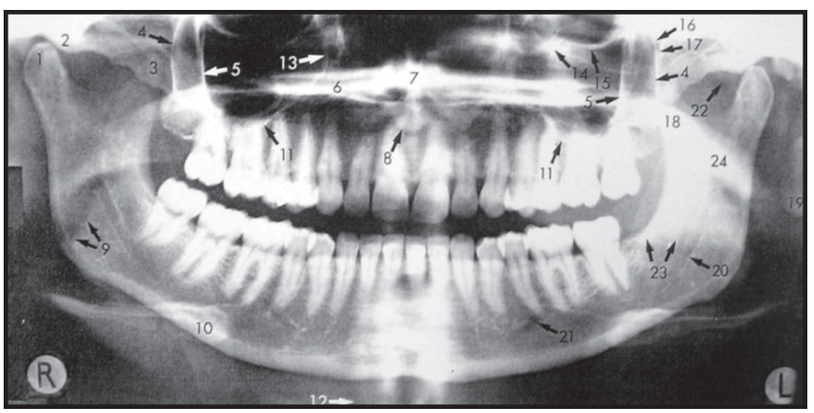


Fig. 13.19A: OPG radiographic view with anatomical landmarks outlined. It is a radiographic technique for producing a single image of the facial structures that includes both the maxillary and mandibular dental arches and their supporting structures. Various structures visible are:
1. Mandibular condyle; 2. Articular eminence; 3. Coronoid process of mandible superimposed on zygomatic process; 4. Posterior wall of maxillary sinus; 5. Posterior wall of zygomatic process of maxilla; 6. Hard palate; 7. Nasal septum; 8. Tip of nose; 9. Dorsum of tongue; 10. Hyoid superimposed over inferior border of mandible; 11. Inferior border of maxillary sinus; 12. Image of cervical spine; 13. Medial border of maxillary sinus; 14. Infraorbital canal; 15. Infraorbital rim; 16. Pterygomaxillary fissure; 17. Anterior border of the pterygoid plates; 18. Lateral pterygoid plates superimposed on soft palate and coronoid process of mandible; 19. Ear lobe; 20. Inferior border of mandibular canal; 21. Mental foramen; 22. Posterior wall of nasopharynx; 23. Inferior border of mandible superimposed from opposite side; 24. Soft palate over mandibular foramen of mandible

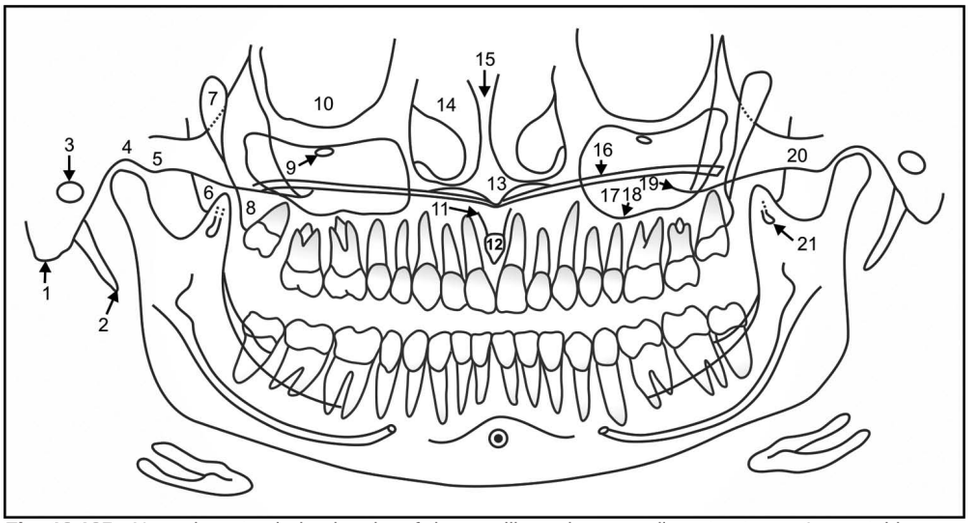


Fig. 13.19B: Normal anatomic landmarks of the maxilla and surrounding structures: 1. mastoid process; 2. styloid process; 3. external auditory meatus; 4. glenoid fossa; 5. articular eminence; 6. lateral pterygoid plate; 7. pterygomaxillary_fissure; 8. maxillary tuberosity; 9. infraorbital foramen; 10. orbit; 11. incisive canal; 12. incisive foramen; 13. anterior nasal spine; 14. nasal cavity and conchae; 15. nasal septum; 16. hard palate; 17. maxillary sinus and floor of the maxillary sinus; 18. zygomatic process of the maxilla 19. zygoma; 20. hamulus; 21. dentition

An additional real shadow is often cast by the vertical plastic head supports.

b. Soft tissue shadows
   - Ear lobes
   - Nasal cartilages
   - Soft palate
   - Dorsum of the tongue
   - Lips and cheeks
   - Nasolabial folds

c. Air shadows
   - Mouth/oral opening
   - Oropharynx

2. Ghost or artifactual shadows; created by the tomographic movement, and cast by the structures on the opposite side or a long way from the focal trough. The 8° upward angulation of the X-ray beam means that these ghost shadows appear at a higher level than the structures that have caused them.
   - Cervical vertebrae
   - Body, angle and ramus of the contralateral side of the mandible
   - Palate.

Bony Landmarks of the Maxilla and Surrounding Structures (Fig. 13.19B)

1. *Mastoid Process*
   Is a marked prominence of bone located posterior and inferior to the temporomandibular joint, it is a part of the temporal bone.
   On the radiograph it appears as:
   - A rounded radiopacity located posterior and inferior to the temporomandibular joint.
   - It is not seen on the periapical radiograph.
2. *Styloid process*
   Is a long pointed and sharp projection of bone that extends downwards from the inferior surface of the temporal bone. It is anterior to the mastoid process.
   On the radiograph it appears as:
   - A long radiopaque spine extending from the temporal bone anterior to the mastoid process.
   - It is not seen on the periapical radiograph.
3. *External auditory meatus (External acoustic meatus)*
   Is an opening in the temporal bone located superior and anterior to the mastoid process.
   On the radiograph it appears as:
   - A round to oval radiolucency anterior and superior to the mastoid process.
   - It is not seen on the periapical radiograph.
4. *Glenoid fossa (Mandibular fossa)*
   It is a concave, depressed area of the temporal bone, in which the mandibular condyle rests. It is located anterior to the mastoid process and the external auditory meatus.
   On the radiograph it appears as:
   - A concave radiopacity superior to the mandibular condyle.
   - It is not seen on the periapical radiograph.
5. *Articular eminence (Articular tubercle)*
   Is a rounded projection of the temporal bone located anterior to the glenoid fossa.

On the radiograph it appears as:
- A rounded radiopaque projection of the bone located anterior to the glenoid fossa.
- It is not seen on the periapical radiograph.

6. *Lateral pterygoid plate*
Is a wing shaped bony projection of the sphenoid bone located distal to the maxillary tuberosity region.
On the radiograph it appears as:
- A radiopaque projection of bone distal to the maxillary tuberosity region.
- It is not seen on the periapical radiograph.

7. *Pterygomaxillary fissure*
Is a narrow space or cleft that separates the lateral pterygoid plate and the maxilla.
On the radiograph it appears as:
- A radiolucent area between the lateral pterygoid plate and the maxilla.
- The zygoma may superimpose and obscure the fissure.
- It is not seen on the periapical radiograph.

8. *Maxillary tuberosity*
On the panoramic radiograph it appears as:
- A radiopaque bulge distal to the third molar region.

9. *Infraorbital foramen*
Is an opening in the bone found inferior to the border of the orbit.
On the panoramic radiograph it appears as:
- A round or oval radiolucency inferior to the orbit.
- It may be superimposed over the maxillary sinus.
- It is not seen on the periapical radiograph.

10. *Orbit*
Is the bony cavity that contains the eye ball.
On the panoramic radiograph it appears as:
- A round radiolucent compartment with radiopaque borders located superior to the maxillary sinus.
- On most panoramic radiographs only the inferior border of the orbit is visible, where it appears as a radiopaque line.

11. *Incisive canal (Nasopalatine canal)*
Is a passage through the bone that extends from the superior foramina of the incisive canal (located on the floor of the nasal cavity) to the incisive foramen (located on the anterior hard palate).
On the panoramic radiograph it appears as:
- A tube like radiolucent area with radiopaque borders.
- It is observed between the maxillary central incisors.

12. *Incisive foramen (Nasopalatine foramen)*
On the panoramic radiograph it appears as
- A small ovoid or round radiolucency located between the roots of the maxillary central incisors.

13. *Anterior nasal spine*
On the panoramic radiograph it appears as
- A "V" shaped radiopaque area located at the intersection of the floor of the nasal cavity and the nasal septum.

14. *Nasal cavity*
On the panoramic radiograph it appears as
- A large radiolucent area above the maxillary incisors.

15. *Nasal septum*
On the panoramic radiograph it appears as
- A vertical radiopaque partition that divides the nasal cavity.

16. *Hard palate*
Is the bony wall that separates the nasal cavity from the oral cavity.
On the panoramic radiograph it appears as
- A horizontal radiopaque band superior to the apices of the maxillary teeth.

17. *Maxillary sinus and floor of the maxillary sinus*
On the panoramic radiograph it appears as
- A paired radiolucencies located above the apices of the maxillary premolars and molars.
- The floor of the maxillary sinus is composed of dense cortical bone and appears as a radiopaque line.

18. *Zygomatic process of the maxilla*
On the panoramic radiograph it appears as
- A "J' or "U" shaped radiopacity located superior to the maxillary first molar.

19. *Zygoma*
On the panoramic radiograph it appears as
- A radiopaque band that extends posteriorly from the zygomatic process of the maxilla.

20. *Hamulus*
On the panoramic radiograph it appears as
- A radiopaque hook-like projection posterior to the maxillary tuberosity area.

21. *Dentition*
On the panoramic radiograph it appears as
- The complete dentition is demonstrated.
- Teeth should be evaluated for gross deformities, like caries, periapical and peridontal disease
- Impacted molars can be observed for their orientation, number of roots, and the relationship of the roots to critical anatomical structures like floor and posterior wall of the maxillary sinus, maxillary tuberosity and adjacent teeth.
- The proximal surfaces of premolars often overlap which inteferes with the detection of caries.
- If the anterior teeth are excessively broad or narrow, it suggests the malpositioning of the patient.
- If the teeth are wider on one side than the other it suggests that the patient's sagittal plane was rotated.

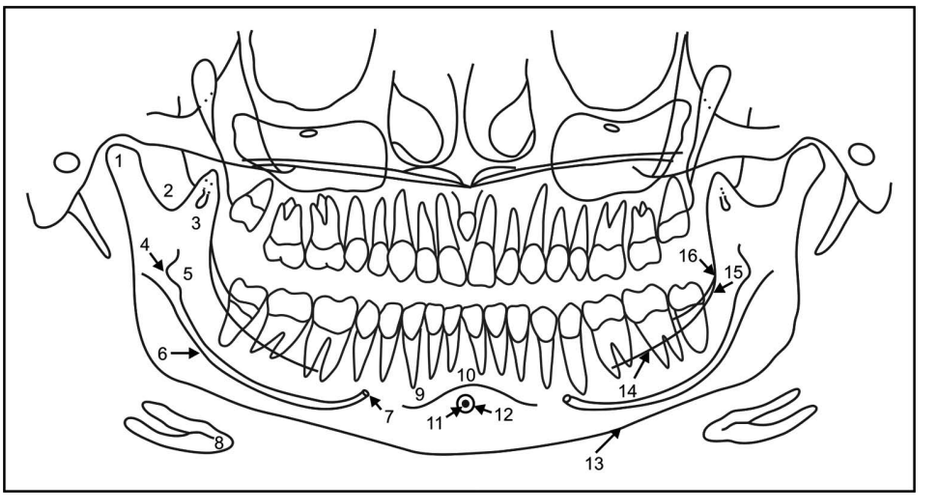


Fig. 13.19C: Normal anatomic landmarks of the mandible and surrounding structures: 1. mandibular condyle; 2. coronoid notch; 3. coronoid process; 4. ramus 5. mandibular foramen; 6. lingula; 7. mandibular canal; 8. mental foramen; 9. mental ridge; 10. mental fossa; 11. lingual foramen; 12. genial tubercles; 13. inferior border of the mandible; 14. mylohyoid ridge; 15. internal oblique ridge; 16. external oblique ridge

Bony Landmarks of the Mandible and Surrounding Structures (Fig. 13.19C)

1. *Mandibular condyle*:
   Is a rounded projection of bone extending from the posterio-superior border of the ramus of the mandible. It articulates with the glenoid fossa of the temporal bone.
   On the panoramic radiograph it appears as
   - A bony rounded, radiopaque projection extending from the posterior border of the ramus of the mandible.
   - It is not seen on the periapical radiograph.
2. *Coronoid notch*:
   Is a scooped out concavity of bone located distal to the coronoid process of the mandible.
   On the panoramic radiograph it appears as
   - A radiolucent concavity located distal to the coronoid process on the superior border of the ramus.
   - It is not seen on the periapical radiograph.
3. *Coronoid process*:
   On the panoramic radiograph it appears as
   - A triangular radiopacity posterior to the maxillary tuberosity region.
4. *Ramus*:
   On the panoramic radiograph,
   Shadows of other structures may be superimposed over the mandibular ramus area,
   - Pharyngeal air way shadow, especially when the patient is unable to expel air and place the tongue in the palate during exposure.
   - Posterior wall of the nasopharynx.
   - Cervical vertebrae, especially in patients with pronounced anterior lordosis (as seen in osteoporotic patients).
   - Ear lobe and ear decorations.
   - Soft palate and uvula.
   - Dorsum of the tongue.
   - Ghost shadows of the opposite side of the mandible.
5. *Mandibular foramen*:
   Is a round or ovoid opening on the lingual aspect of the ramus of the mandible.
   On the panoramic radiograph it appears as
   - A round or ovoid radiolucency centered within the ramus of the mandible.
   - It is not seen on the periapical radiograph.
6. *Lingula*:
   A a small tongue shaped projection of bone seen adjacent to the mandibular foramen.
   On the panoramic radiograph it appears as
   - An indistinct radiopacity anterior to the mandibular foramen.
   - It is not seen on the periapical radiograph.
7. *Mandibular canal*:
   On the panoramic radiograph it appears as
   - A radiolucent band outlined by two thin radiopaque lines representing the cortical walls of the canal.
8. *Mental foramen*:
   On the panoramic radiograph it appears as
   - A small ovoid or round radiolucency located in the apical region of the mandibular premolars.
9. *Mental ridge*:
   On the panoramic radiograph it appears as
   - A thick radiopaque band that extends from the mandibular premolar region to the incisor region.
10. *Mental fossa*:
    On the panoramic radiograph it appears as
    - A radiolucent area above the mental ridge.

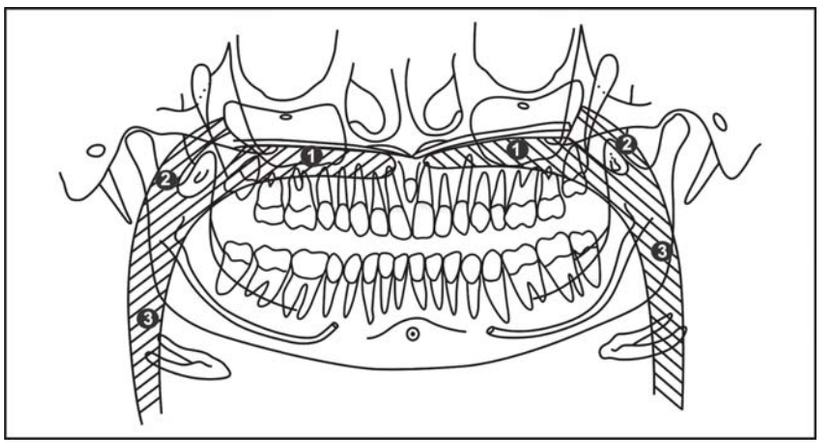


Fig. 13.19D: Air space images seen on panoramic films: 1. palatoglossal air space; 2. nasopharyngeal air space; 3. glossopharyngeal air space

11. *Lingual foramen*:
    On the panoramic radiograph it appears as
    - A small radiolucent dot located inferior to the apices of the mandibular incisors.
12. *Genial tubercles*:
    On the panoramic radiograph it appears as
    - A ring shaped radiopacity surrounding the lingual foramen.
13. *Inferior border of the mandible*:
    Is a linear prominence of cortical bone that defines the lower border of the mandible.
    On the panoramic radiograph it appears as
    - A dense radiopaque band that outlines the lower border of the mandible.
14. *Mylohyoid ridge*:
    On the panoramic radiograph it appears as
    - A dense radiopaque band that extends downward and forward from the molar region.
15. *Internal oblique ridge*:
    On the panoramic radiograph it appears as
    - A dense radiopaque band that extends downward and forward from the ramus.
16. *External oblique ridge*:
    On the panoramic radiograph it appears as
    - A dense radiopaque band that extends downward and forward from the anterior border of the ramus of the mandible.
17. *Angle of the mandible*:
    Is that area of the mandible where the body meets the ramus.
    On the panoramic radiograph it appears as
    - A radiopaque bony structure where the ramus joins the body of the mandible.
18. *Dentition*:
    On the panoramic radiograph it appears as
    - The complete dentition is demonstrated.
    - Teeth should be evaluated for gross deformities, like caries, periapical and peridontal disease
    - Impacted molars can be observed for their orientation, number of roots, and the relationship of the roots to critical anatomical structures like the mandibular canal and adjacent teeth.
    - The proximal surfaces of premolars often overlap which interferes with the detection of caries.
    - If the anterior teeth are excessively broad or narrow, it suggests the malpositioning of the patient.
    - If the teeth are wider on one side than the other it suggests that the patient's sagittal plane was rotated.

Air Space Images Seen on Panoramic Radiographs (Fig. 13.19D)

1. *Palatoglossal air space*:
   Is the space between the palate and the tongue.
   On the panoramic radiograph it appears as
   - A horizontal radiolucent band located above the apices of the maxillary teeth.
2. *Nasopharyngeal air space*:
   Is that portion of the pharynx located posterior to the nasal cavity.
   On the panoramic radiograph it appears as
   - A diagonal radiolucency located superior to the radiopaque shadow of the soft palate and uvula.
3. *Glossopharyngeal air space*:
   Is that portion of the pharynx located posterior to the tongue and the oral cavity.
   On the panoramic radiograph it appears as
   - A vertical radiolucent band superimposed over the ramus of the mandible.
   - It is continuous with the nasopharyngeal air space superiorly and the palatoglossal air space inferiorly.

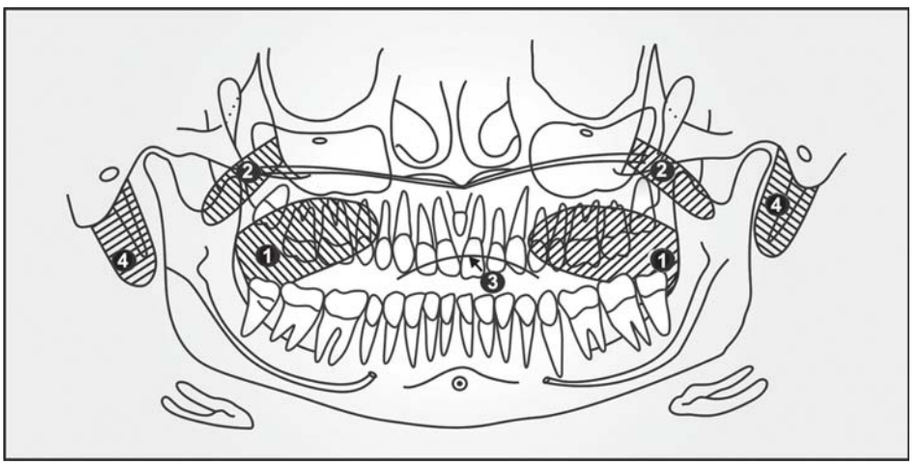


Fig. 13.19E: Soft tissue images seen on panoramic films: 1. tongue; 2. soft palate and uvula; 3. lipline; 4, ear

Soft Tissue Images Seen on Panoramic Radiographs (Fig. 13.19E)

1. *Tongue*:
   Is a movable muscular structure attached to the floor of the mouth.
   On the panoramic radiograph it appears as
   - A radiopaque area superimposed over the maxillary posterior teeth.
2. *Soft palate and uvula*:
   These form a muscular curtain that separates the oral cavity from the nasal cavity.
   On the panoramic radiograph it appears as
   - A diagonal radiopacity projecting posteriorly and inferiorly from the maxillary tuberosity region.
3. *Lip line*:
   Is fomed by the position of the patient's lips.
   On the panoramic radiograph it appears as
   - The lip line is seen in the region of the anterior teeth.
   - The areas of the teeth not covered by the lips appear more radiolucent.
   - The areas of the teeth covered by the lips appear more radiopaque.
4. *Ear*:
   On the panoramic radiograph it appears as
   - A radiopaque shadow that projects anteriorly and inferiorly from the mastoid process.
   - The ear is viewed superimposed over the styloid process.

Computed Panoramic Tomography with Scanner Simulated Luminescence

Images obtained by panoramic tomography are characteristically blurred and not detailed enough to show fine bony abnormalities. This new computed system is used to temporarily store the X-ray energy pattern. The image receptor converts the latent image into digital signals which are processed and recorded onto the film.

Advantages

1. Reduced radiation exposure.
2. Better diagnostic quality.
3. Contrast and spatial frequency enhancement.

Reverse Panoral Radiograph

This technique of reverse panoral radiography is one way in which a panoramic X-ray machine is used to provide a clearer and less distorted view of the ascending ramus and it's process and the adjacent structures with the mouth open or closed.

Disadvantages

- Positioning of the patient is critical and difficult.
- Exposure to the eyes is more.

BIBLIOGRAPHY

1. Allan B Reskin. Advances in Oral Radiology, PSG Publishing Co. 1980.
2. Goaz PW, White SC. Panoramic Radiography, Radiographic Examinations In Oral Radiology, Principles and Interpretation, 3rd ed. St. Louis, Mosby- year book, 1994; 314-38.
3. Johnson ON, McNally MA, Essay CE. The Periapical Examination Essentials of Dental Radiography for Dental Assistants and Hygienists, 6th ed. Norwalk, Appleton and Lange, 1999; 319-90.
4. Karjodkar FR, Nahar P. Ghost Images which Haunt OPG, Dental Voice, IDA, March 2002.
5. Karjodkar FR. Trouble Shooting Errors in Panoramic Techniques. Dental Voice, IDA, March 1999.
6. Langland OE, Langlis RP, McDavid WD, et al. Panoramic Radiology, 2nd ed. Philadelphia, Lea and Febiger, 1989; 224-71.
7. Mason-Hing LR. In Fundamentals of Dental Radiography, 3rd ed., Philadelphia, WB Saunders, 1993; 1-75.

14

Specialized Radiographic Techniques and Recent Advances

OTHER RADIOGRAPHIC TECHNIQUES AND ADVANCES

Tomography

Is a process by which an image layer of the body is produced, while the images of the structures above and below that layer are made invisible by blurring.

In normal radiography, the character of the pattern on the radiograph formed by the anatomical structures of interest is very often partially or sometimes even completely obscured by the shadows cast by the over lying or under lying structures. In many cases a distinction can be made by choosing appropriate orientation of the patient, but in others it is necessary to use a technique known as 'body section radiography' or 'Tomography'.

Tomography may be classified into three types:

a. Conventional tomography.
b. Computed tomography.
c. Emission tomography.

a. Conventional Tomography (Figs 14.1A and B)

Tomography is a generic term, formed from the Greek words tomo (slice) and graph (picture), that was adopted in 1962 by the International Commission on Radiographic Units and Measurements to describe all forms of body section radiography.

Body section radiography is a special X-ray technique that enables visualization of a section of the patient's anatomy by blurring regions of the patient's anatomy above and below the section of interest.

This is achieved by a synchronized movement of the film and the tube in opposite directions, about a fulcrum (i.e. the plane of interest in the patient's body) (Fig. 14.1C).

Objects closest to the film are seen most sharply and objects farthest away are completely blurred.

The thickness of the image layer depends on the angle of rotation or the amount of movement of the tube, thus if the path of the X-ray tube is short, and the angle is small then the image layer is relatively thick. Whereas, the angle of the movement increases, the thickness of the image layer decreases.

Some degree of image degradation also occurs within the image layer. The greatest amount of blurring is at the periphery of the image layer, and the sharpest image is at the center.

The principles of tomography can be mechanically implemented in a variety of ways (Fig. 14.1D):

- The tube and the film move synchronously in a straight line in opposite directions in parallel planes.
- The tube and the film move synchronously in opposite directions in parallel planes, but with motions other than a straight line, i.e. circular, cross, spiral, hypocycloidal, trispiral and other multidirectional movements.
- The X-ray tube may move in arcs rather than in flat planes.

The blurring of objects outside a focal plane is accomplished most effectively by compound movements of the X-ray tube and least effective by simple movements.

There are two basic design options used in most units:

- Adjustable fulcrum system- the image layer or plane of focus is changed by adjusting the point of rotation called the fulcrum. The disadvantage of this system is that the images that are produced will have different amount of magnification, depending on the relative position of the fulcrum between the tube and the film.
- The second design is so made that the distance between the fulcrum and the tube and the fulcrum and the film

Fig. 14.1A: Linear tomogram of the TMJ. Note the horizontal radiopaque streaks in this image. These streaks are called parasite lines, represent the blurred image of objects lying outside the focal plane. They are evident in the image when the long axis of the objects located superficial or deep to the focal plane lie parallel with the path of the X-ray tube and film movement

Fig. 14.1B: Spiral tomogram of the TMJ, complex tomographic movements result in maximal blurring of the images of objects lying superficial and deep to the plane of focus; the streaking parasite lines, therefore are absent

remains constant. In this case the film and the X-ray tube pass in opposite directions through proportional arcs. Here the object of interest is positioned with reference to the focal plane, and all the images contain the same degree of magnification.

Tomographic views are used to examine various facial structures:

i. Tomography of sinuses.
   Affords the following advantages
   - It gives a more precise evaluation of sinus pathologies, which are poorly visualized on routine radiography.

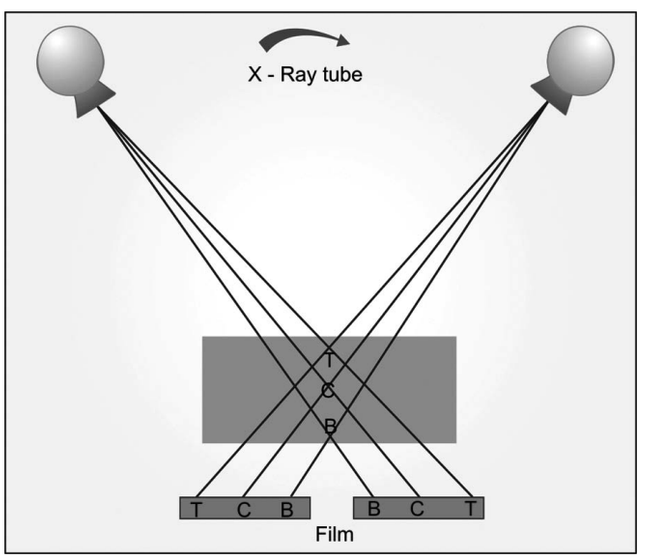


Fig. 14.1C: The tube and the film are rotated around a fulcrum (C) during an exposure. When the exposure is initiated, objects at the top of the body being examined (T) are on the right side of the film while objects in the center of the body (C) lie in the center of the film and objects at the bottom of the body (B) lie at the left side of the film. During exposure, the positions of B and T reverse while the position of C remains constant

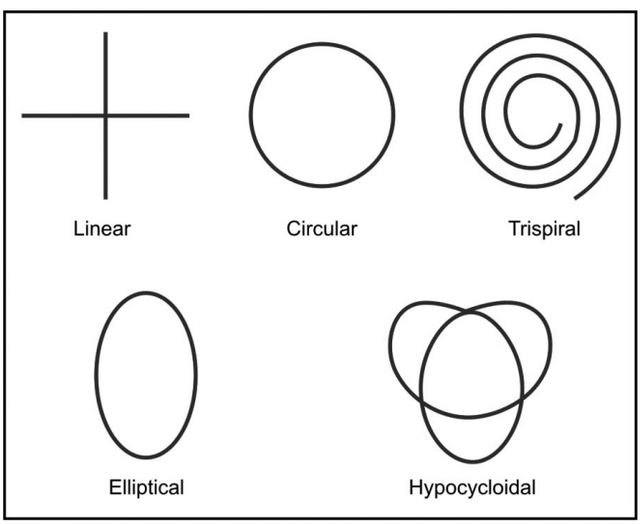


Fig. 14.1D: Common kinds of tomographic movements. The more complex the motion the smaller the likelihood that the X-ray beam will strike an object of importance at the same tangent through an entire exposure. Therefore, blurring will be less dependent upon the orientation of the object under study

- When a pathology is strongly suspected clinically, but plain films are negative.
- Sphenoid and ethmoidal sinuses are more clearly visualized.

ii. Tomography of facial bones, to study facial fractures. Extent of orbital blow-out fractures.
iii. Tomography of the mandible.
iv. Tomography of the temporo mandibular joint, especially when the patient is unable to open his mouth or in conjunction with arthrography.
v. For dental implant patients.

b. Computed Tomography (Figs 14.2A and B)

The discovery and development of CT revolutionized medical imaging. CT is a digital and mathematical imaging technique that creates tomographic sections where the tomographic layer is not contaminated by blurred structures from adjacent anatomy. It enables differentiation and quantification of both hard and soft tissues, and is an non invasive procedure.

CT scanners use X-rays to produce sectional images, but the radiographic film is replaced by very sensitive crystal or gas detectors. The detectors measure the intensity of the X-ray beam emerging from the patient and convert this into digital data which is stored and manipulated by the computer. The numerical information is converted into gray scale representing different tissue densities, allowing a visual image to be generated.

This can provide tomographic sections of the body.

It has the ability to detect minute differences in tissue alterations.

It gives highly accurate quantitative information about the tissues imaged.

Indications

- Investigations of intracranial diseases including tumors, hemorrhage and infarcts.
- Investigations of suspected intracranial and spinal cord damage following trauma to the head and neck.
- Assessment of fractures involving:
  - The orbits and naso-ethmoidal complex.
  - The cranial base.
  - The odontoid peg.
  - The cervical spine.
- Tumor staging- assessment of site, size and extent of benign and malignant tumors affecting:
  - The maxillary antra
  - The base of the skull
  - The pterygoid region
  - The pharynx
  - The larynx.
- Investigations of tumors and tumor like discrete swellings intrinsic and extrinsic to the salivary glands.
- Investigation of the TMJ.
- Preoperative assessment of maxillary alveolar bone height and thickness before inserting implants.

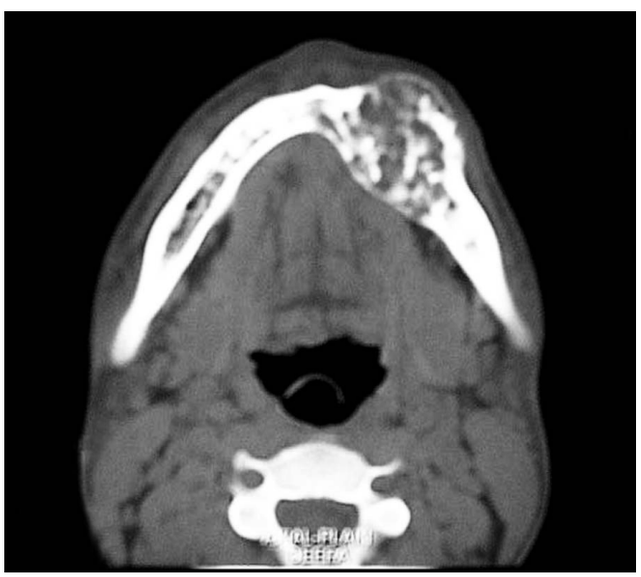


Fig. 14.2A: CT showing axial view of the left side mandible-fibrosseous lesion

Fig. 14.2B: CT showing coronal view of the left side mandible- fibrosseous lesion

Equipment

- The X-ray Gantry.
  i. The X-ray tube.
     – Stationary anode energised continuously.
     – Rotating anode operated in impulse mode.
  ii. The radiation detector.
     – Scintillation detectors.
     – Gas counters.
  iii. The ancillary components.
  This embodies the mechanical system providing the motions required.
  The CT sections are reconstructed from profile X-rays taken at different angles from the structure to be imaged.
- The computer system.
  The data collected by the radiation detectors in the X-ray gantry are utilized for reconstruction of the tomographic section. The reconstructed section is displayed either in the analog form as an image or as a numerical print out.
  These functions are carried out by the computer system.
  A computed tomographic image is initiated by a process called scanning. Beams from one or several small X-ray sources are passed through the body and intercepted by one or more radiation detectors. These detectors produce electrical impulses that are proportional to the intensity of the X-ray beam emerging from the body. That intensity is determined by various factors; the energy of the X-ray source, the distance between the source and the detector, the attenuation of the beam by the material in the object being scanned.
  In its simplest form a CT scanner consists of a radiographic tube that emits a finely collimated, fan-shaped X-ray beam directed to a series of scintillation detectors or ionization chambers.
  Depending on the scanner's mechanical geometry,
  – Both the radiographic tube and detectors may, rotate synchronously about the patient (Fig. 14.3). Or
  – The detectors may form a continuous ring around the patient and the X-ray beam may move in a circle within the detector ring (Incremental Scanners). Or
  – Spiral or helix scanners, here the gantry containing the X-ray tube and detectors revolves around the patient, the table on which the patient is lying continuously advances through the gantry. This results in the acquisition of a continuous spiral data, which provides multiplanar image reconstructions, reduced examination time and a reduced radiation dose (Fig. 14.4).

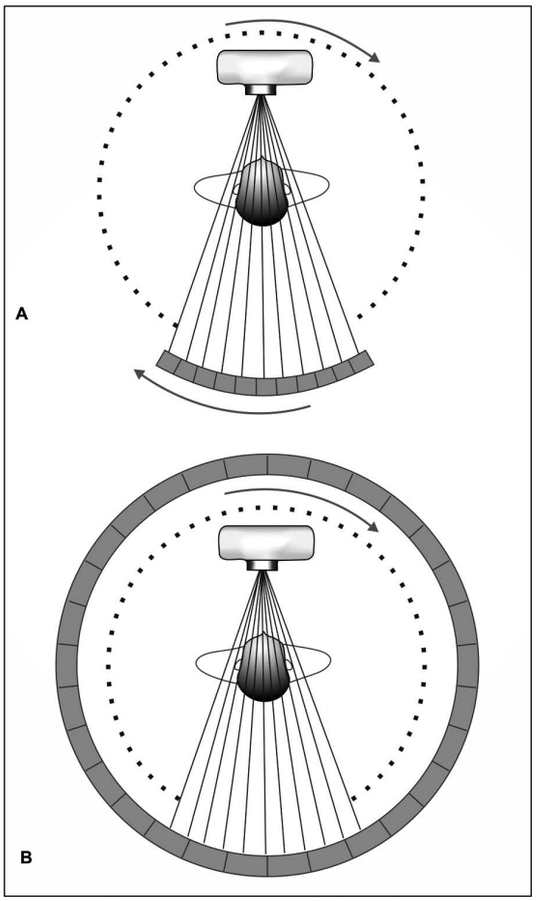


Fig. 14.3: Mechanical geometry of CT scanners. **A.** Both the X-ray tube and the detector array revolve around the patient. **B.** Only the X-ray tube rotates, radiation detection is accomplished by the use of a fixed circular array of as many as 1000 detectors

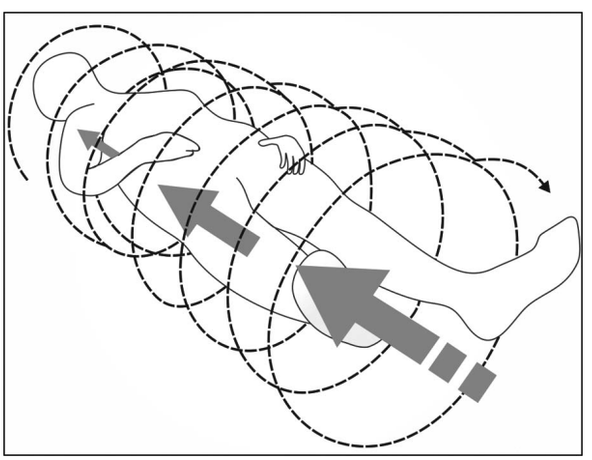


Fig. 14.4: Principles of helical CT. As the patient is moved through the gantry, the continuously rotating X-ray tube and detector describe a helical or spiral path about the patient, acquiring image data as they rotate

The CT image is a digital image, reconstructed by the computer, which mathematically manipulates the transmission data obtained from the multiple projections. Penetration profile is stored in the computer, which calculates the density or absorption at points on a grid formed by the intersections of penetrating profiles. The image consists of a matrix of individual points or pixels. The size of the pixel is determined by:

- the geometry of the scan,
- the frequency and spacing of measurements,
- the number of penetration profiles and
- the size of the X-ray source and detector.

Each number or pixel represents a calculation of the actual attenuation of the X-ray beam by materials with the body. It represents the absorption characteristics, or linear attenuation coefficient, of that particular volume of tissue in the patient. CT numbers, also known as Hounsfield units, may range from –1000 to + 1000, each constituting a different level of optical density. The scale of relative densities is based on air (–1000), water (0) and dense bone (+1000). The numbers may vary from one machine to another depending upon various factors. For any particular unit and energy, numbers describing the attenuation of biological materials with densities lying between hair and bone can be described. Since the numbers represent attenuation or density, the computer constructs an image by printing the numbers or by assigning different degrees of grayness or different colors to each number.

The CT image is recorded and displayed as a matrix of individual blocks called 'voxels' (volume elements). Each square of the image matrix is a pixel. Whereas a pixel (about 0.1 mm) is determined partly by the computer program used to construct the image, the length of the voxel (about 1 to 2 mm) is determined by the width of X-ray beam, which in turn is controlled by the prepatient and postpatient collimators. Voxel length is analogous to the tomographic layer in film tomography.

Dentascan Imaging

Provides programmed reformation, organization and display of the imaging study. The radiologist simply has to indicate the curvature of the mandibular or maxillary arch and the computer is programmed to generate referenced cross-sectional and tangential/panoramic images of the alveolus along with three-dimensional images of the arch. The limitations of the dentascan is that the image may not be of the true size and requires compensation for magnification, it has a limited range of diagnostic gray scale, determination of the bone quality requires other aids. A diagnostic template used for implant imaging is very useful.

Three-Dimensional CT

Multiplanar CT images are two-dimensional and require a certain degree of mental integration by the viewer for interpretation, this led to the development of computer programs that reformat the acquired data from axial CT scans into three-dimensional images (3D CT).

3D CT imaging techniques may be divided into the following groups:

- Multiplanar reformatting (MPR) and dental MPR (Fig. 14.5)
- Shaded surface display (SSD)
- Volume rendering
- Maximum intensity projection (MIP)
- Model production and virtual reality.

Three-dimensional reformatting requires that each original voxel, shaped as a rectangle parallel piped or rectangular solid, be dimensionally altered into multiple cuboidal voxels. This process is called interpolation, and

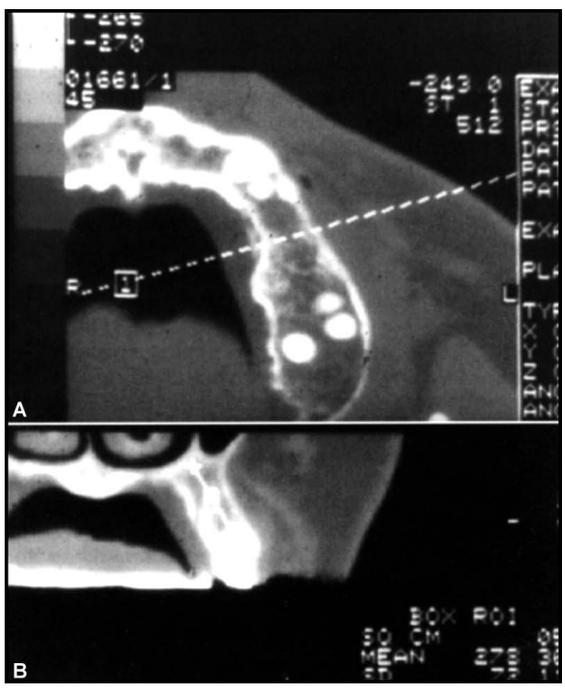


Fig. 14.5: Reformated CT images. **A.** axial view of the maxilla with reformatted image position identified by the dotted line. **B.** resulting reformation and cross sectional view of the maxillary sinus anterior recess, floor of the nasal cavity and lower turbinate. Trabecular bone in this region is measured using a region of interest and measures 178 Hounsfield units

this creates sets of evenly spaced cuboidal voxels that occupy the same volume as the original voxel. Creation of these new cuboidal voxels allows the image to be reconstructed in any plane without loss of resolution by locating their position in space relative to one another. In construction of the 3D CT image only cuberilles representing the surface of the object scanned are projected onto the viewing monitor. The surface formed by these cuberilles may then appear as if illuminated by a light source located behind the viewer. Thus the visible surface of each pixel is assigned a gray-level value, depending upon its distance from and orientation to the light source. Thus the pixel that faces the light source and/or are closer appears brighter than those turned away from the source and/or are farther away. Once constructed the 3D CT image may be further manipulated by rotation about any axis to display the structure imaged from many angles. Also, external surfaces of the image can be removed electronically to reveal concealed deeper anatomy.

This is very useful for craniofacial reconstructive surgery and has been used both for treatment of congenital and acquired deformities and for evaluation of intracranial tumors, benign and malignant lesions of the maxillofacial complex, cervical spine injuries, pelvic fractures and deformities of the hands and feet. The availability of data in a three-dimensional format also has allowed the construction of life sized models that can be used for trial surgeries and the construction of surgical stents for guiding dental implants as well as creation of accurate implanted prostheses.

Interactive computed tomography (ICT), is a technique that has been developed to bridge the gap in information transfer between the radiologist and the clinician, in the form of a computer file.

Advantages of CT

- Structural relationships of hard and soft tissues can be observed directly. Differences between tissues that differ in physical density by less than 1 percent can be distinguished.
- The ability to rotate images and to add or subtract structural components permits relationships to be studied.
- Contiguous structures can be separated and normal hidden surfaces examined in detail.
- Accurate linear and volumetric measurements can be made.
- Changes in linear or volumetric measures can be determined by sequential scans (e.g. remodeling of bone).
- Eliminates superimposition of images of structures outside the area of interest.
- A single CT imaging procedure consisting of either multiple contiguous or one helical scan can be viewed as images in the axial, coronal or sagittal planes, depending on the diagnostic task (multiplanar reformatted imaging).

Limitations

- Since the measurements or pixels that form the image represent discrete subdivisions of space, the effect of blurring is much greater than in conventional radiographic systems.
- The resolution of the image is also limited by the size represented by the pixel, which is generally greater than the size of the silver specks that form the conventional radiographs.
- The detail of a computed tomographic image is not as fine as that obtainable on other radiographs.
- Its application in longitudinal monitoring of implant prosthesis is limited and contraindicated because of the image artifact created by metals that would obscure the information.
- Metallic objects such as fillings produce marked streak artifacts across the CT image
- The equipment is very expensive.

Cone Beam Radiography (Fig. 14.6)

This technique is a recent development and is found to be more efficient and economical than conventional tomography or CT for oral diagnosis.

Cone Beam CT (CBCT) uses a round or rectangular cone shaped X-ray beam centered on a two-dimensional X-ray sensor to scan a 360° rotation about the patient's head. During the scan a series of 360 exposures or projections, one for each degree of rotation, is acquired, which provides the raw digital data for reconstruction of the exposed volume by computer algorithm. Depending on the equipment, scan time range from 17 seconds to approximately more than a minute. Multiplanar reformatting of the primary reconstruction allows for both three-dimensional images and two dimensional images of any selected plane to be made. The visual resolving power of these systems varies up to about 21p/mm, four times that of CT. The final images may be printed on a 1: 1 scale with geometric accuracy to about 2 percent or less.

Cone Beam CT is less expensive than CT, and comparatively free of the labor-intensive costly service. The radiation dose delivered to the patient is only 3 to 20 percent of that of a conventional CT scan.

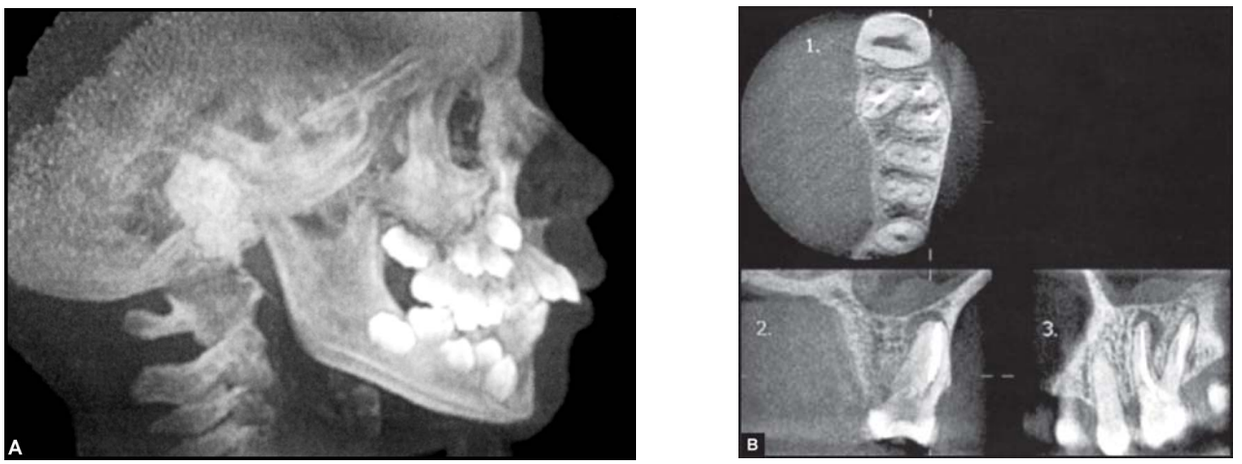


Fig. 14.6: Cone Beam Computed tomography. Multiplanar reformating of the primary image reconstruction allows for images of any body plane to be made.

A. NewTom image showing lateral cephalometry view (8 bit image) with post processing to reveal soft tissue of the face, facial bones and developing dentition. **B.** 3D Accuitomo image of maxillary first molar with periapical disease at apex of mesiobuccal root, thickening of PDL, at mid portion of distobuccal root and thickening of the mucoperiosteal lining of the maxillary sinus. Views 1-3 are in the axial, coronal and sagittal planes respectively

At present two systems are available – 3D Accuito and the New Tom Plus.

Scanography (Fig. 14.7)

This is a technique that uses a narrowly collimated, fan shaped beam of radiation to scan an area of interest, sequentially projecting image data relative to this area onto a moving film (similar to that in panoramic radiography). Scanographs produce images with higher contrast and greater detail and this a better image quality than a standard transmission radiograph.

Fig. 14.7: Lateral linear scanogram of the maxillofacial area. Maximal image contrast is obtained by using linear scanning techniques rather than standard radiography

The Soredex Scanora is a commercially available X-ray unit capable of performing both rotational and linear scanography.

In rotational scanography the beam of radiation rotates about a fixed axis that is a predetermined based on the area imaged. This results in the production of two to four scanograms, each made with the X-ray tube in a different position, thus multiple images are made, which can be viewed on the stereoscope. This is found to be useful in the assessment of periodontal disease and detection of periapical lesions.

In linear scanography the X-ray beam and the film move in a linear fashion, scanning the area of interest. Linear scanography can be thought of as panoramic radiography that has been "straightened out". The Scanora system can make both posteroanterior and lateral linear scanning of the maxillofacial complex.

Magnetic Resonance Imaging (MRI) (Figs 14.8A to C)

This technique was first announced by Lauterber in 1972.

This technique relies on the phenomenon of nuclear magnetic resonance to produce a signal that can be used to construct an image. It uses the nonionizing radiation from

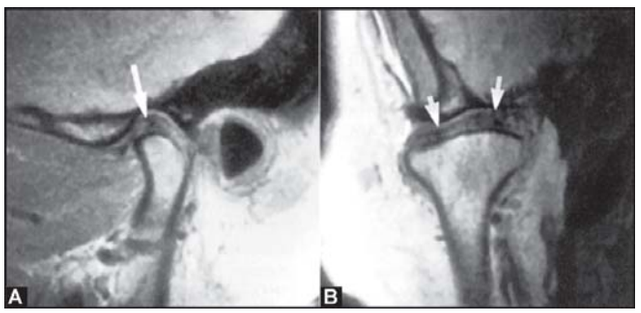


Fig. 14.8A: MRI of a normal TM joint **A.** Closed view showing the condyle and the temporal component. The biconcave disk is located with its posterior band over the condyle. **B.** Coronal image showing the osseous components and disk superior to the condyle

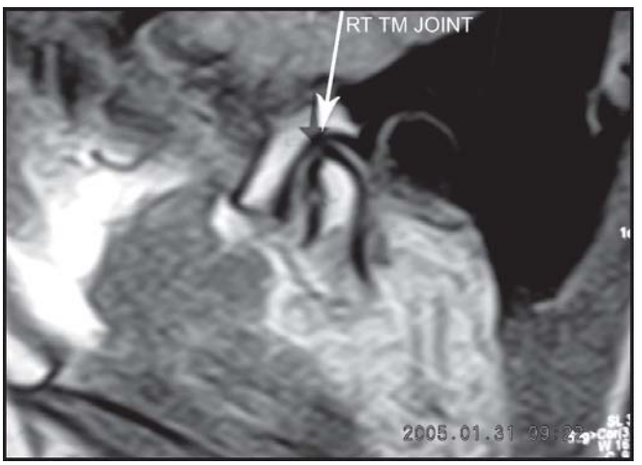


Fig. 14.8B: MRI of a TM joint in the sagittal plane

the radiofrequency (RF) band of the electromagnetic spectrum. Because of its excellent soft tissue contrast resolution, MRI has proved useful in a variety of circumstances, diagnosing a suspected internal derangement of the TM joint and evaluating the treatment of the derangement after surgery, identifying and localizing orofacial soft tissue lesions and providing images of the salivary gland parenchyma.

The patient is placed inside a large magnet, which induces a relatively strong external magnetic field. This causes the nuclei of many atoms of the body, including hydrogen, to align themselves with the magnetic field. After application of an RF signal, energy is released from the body, detected and used to construct the MR image by the computer.

When nuclei are subjected to the flux of an external magnetic field, two energy states result; spin-up, which is in the direction of the field, and spin-down which is in the opposite direction of the field. The combined effect of these two energy states is a weak net magnetic moment, or magnetic vector (Mv), parallel with the applied magnetic field. As soon as the radio waves are turned off (the resonant RF pulse), two events occur simultaneously – the radiation of energy and the return of the nuclei to their original spin state at a lower energy. This process is called relaxation, and the energy loss is detected as a signal, which is called free induction decay (FID):

- First the nuclei in transverse alignment begin to realign themselves with the main magnetic field (i.e. to relax). Relaxation is accomplished by a transfer of energy from individual hydrogen nuclei (spin) to the surrounding molecules (lattice). The time constant that describes the rate at which net magnetization returns to equilibrium by this transfer of energy is called the T1 relaxation time or spin-lattice time. T1 varies with different tissues and ability of the nuclei to transfer their excess energy to their environment. A T1 weighted image is produced by a short repetition time between RF pulses and a short signal recovery time. Because T1 is an exponential growth time constant, a tissue with a short T1 produces an intense MR signal, displayed as bright white in a T1 weighted image. A tissue with a long T1 produces a low intensity signal and appears dark in the MR image.
- Second, the magnetic moments of the adjacent hydrogen nuclei begin to interfere with one another, this causes the nuclei to dephase, with a resultant loss of transverse magnetization. The time constant that describes the rate of loss of transverse magnetization is called the T2 relaxation time or transverse (spin-spin) relaxation time. A T2–weighted image is acquired using a long repetition time between RF pulses and a long signal recovery time.

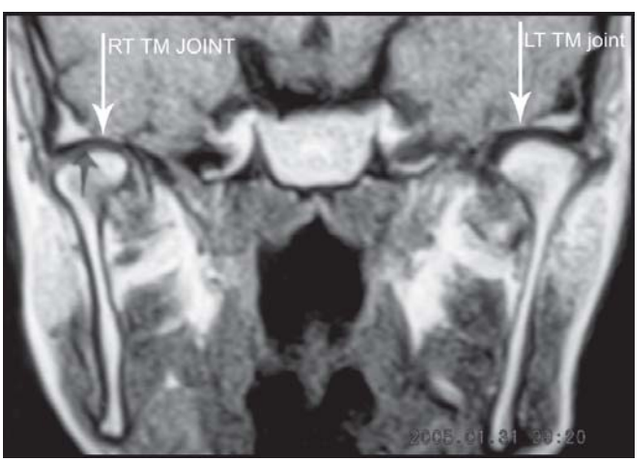


Fig. 14.8C: MRI of a TM joint in the coronal plane

A tissue with a long T2 produces a high intensity signal and a dark image.

T1 weighted images are called fat images, because fat has the shortest T1 relaxation time, and thus it appears bright in the image. T1 gives a good image contrast and T1 weighted images are helpful for depicting small anatomical regions like TM joint. In T1 weighted images cerebrospinal fluid appears black.

T2–weighted images are called water images because water has the longest T2 relaxation time and appears bright in the image. These T2 weighted images are used when one is looking for inflammatory or pathologic changes.

In T2 weighted images cerebrospinal fluid appears white.

Indications

- Assessment of intracranial lesions involving particularly the posterior cranial fossa, the pituitary and the spinal cord.
- Tumor staging- evaluation of the site, size and extent of soft tissue tumors and tumor like lesions, involving
  - The salivary glands.
  - The pharynx.
  - The larynx.
- Investigations of the TMJ to show the hard and soft tissue components of the joint including the disk.

Advantages

- No ionizing radiation.
- No biological effects due to absence of radiation exposure.
- Higher soft tissue contrast.
- Excellent differentiation between soft tissues is possible between normal and abnormal tissues.
- Blood vessels clearly seen.
- The region of the body imaged in MRI is controlled electronically, direct multiplanar imaging is possible without reorienting the patient.
- High resolution images can be constructed in all planes.
- There is no need for enhancement of images using intravenous contrast media with their associated risks.

Limitations

- Expensive.
- Potential hazard imposed by the presence of ferro-magnetic metals in the vicinity of the imaging magnet.
- Patients with cardiac pace makers, insulin pumps and ferromagnetic implants cannot be investigated by MRI.
- Metallic objects in the oral cavity such as appliances, crowns, etc. may cause artifacts.
- Endotracheal tubes need to be replaced by plastic.
- Claustrophobic procedure.
- Relatively long imaging times.
- Cortical bone is not imaged, the signal obtainable is only for the bone marrow.
- The very powerful magnets pose problems with sitting of the equipment.
- Equipment is very expensive.
- Facilities are not widely available.

Nuclear Medicine (Figs 14.9A and B)

Human disease can exist with no specific anatomic changes. Changes that are seen may simply be later effects of some biochemical process that remains undetected until physical symptoms develop. Radionuclide imaging (or functional imaging) provides the only means of assessing physiologic change that is a direct result of biochemical alteration.

Radioisotope imaging uses radioactive compounds that have an affinity for particular tissues- so-called target tissues. These radioactive compounds are injected into the patient, concentrated in the target tissue and their radiation emissions are then detected and imaged, usually using gamma camera. This investigation allows the function and/or the structure of the target tissue to be examined under both static and dynamic conditions.

Indications

- Investigations of salivary gland functions.
- Tumor staging- assessment of sites and extent of bone metastases.
- Evaluation of bone grafts.
- Assessment of continued growth in condylar hyperplasia.
- Investigation of the thyroid.
- Brain scans and assessment of the break down of the blood-brain barrier.

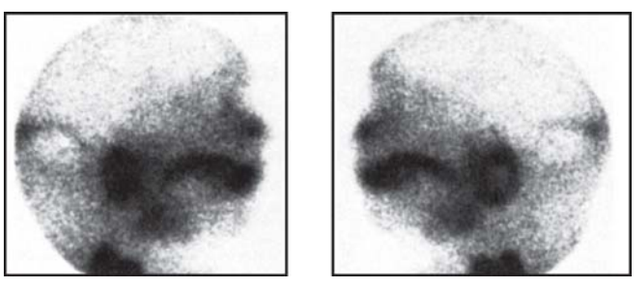


Fig. 14.9A: Right and left static images taken during salivary gland scan, 30 minutes after 99m TcO_4^- administration. A sharply demarcated area of diminished tracer uptake is seen in the left parotid gland. This area proved to be a benign mixed tumor

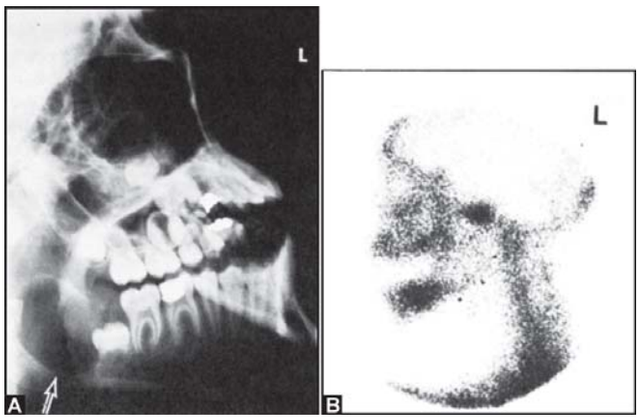


Fig. 14.9B: A. A 14-year-old female patient presented with a large asymptomatic cyst like lesion in the left mandibular ramus associated with an impacted third molar. A. Lateral oblique radiograph of the left mandible. **B.** Left lateral bone scan static image. Note the slight indication of undulation at inferior border of the lesion on the radiograph, and the substantial periapical pathology of the first molar. The scan shows an area of increased uptake in the mandibular body, probably reactive bone formation associated with the periapical pathology. An ill-defined area of diminished tracer uptake is seen in the ramus possibly surrounded, in part, by a thin border of increased uptake, a somewhat typical appearance for a bony cyst on a bone scan. Uptake is greatest at the inferior aspect, but this may be associated with the periapical pathology. The lesion proved to be a dentigerous cyst with a mural ameloblastoma at the inferior aspect

Nuclear medicine procedures are similar to those of conventional diagnostic radiology in that ionizing (X-rays with energies of 20 to 510 kilo electron volt is used to generate an image, and a film looking some what like a radiograph is produced. However there are major differences:

- The patient, rather than the machine, is the source of radiation.
- The detection instrument is different.
- The sensitivities of nuclear medicine procedures are very great.
- The specificities of the nuclear medicine procedures are very low.

Radionuclide imaging is based on the radiotracer method, which assumes that radioactive atoms or molecules in an organism behave in a manner identical to that of their stable counter parts because they are chemically indistinguishable. Radio tracers allow measurement of tissue functions *in vivo* and provide an early marker of disease through measurements of biochemical change. Radionuclide-labeled tracers are used in quantities well below amounts that are lethal to cells.

The various radionuclide-label tracers which are used are:

- Technetium pertechnetate (99m Tc-pertechnetate)- salivary gland, thyroid, bone, blood, liver, lung and heart.
- Iodine (131 I)- thyroid.
- Gallium (67 Ga)- tumors and inflammation.
- Selenium (74 Se)
- Krypton (81 Kr)- lung

The use of tracers for diagnostic imaging became possible with the development of the rectilinear scanner and the gamma scintillation camera. Both these instrument record the gamma emissions from patients injected with appropriate tracers. The cameras use a scintillation crystal that has the ability to fluoresce on interaction with gamma rays. The fluorescence is detected by a photomultiplier tube that magnifies and amplifies the signal. The amplified signal is digitized and used to produce an image by computer algorithm. Use of a scintillation crystal for obtaining data for image formation has led to this technique being labeled as scintigraphy.

The newer procedures are those using:

- Single Photon Emission Computed Tomography (SPECT)
- Positron Emission Computed Tomography (PET)

Bone scan: In contrast to a radiograph, a bone scan gives no information on the morphology of a lesion, either internally or in areas of bone adjacent to the lesion. The scan does demonstrate, however, areas of altered bone metabolism within and around the lesion, thus allowing a reasonably accurate assessment of the growth of a lesion and extent of its borders. Bone scan also allows to view the entire skeleton with no additional radiation burden to the patient. Positive finding usually lead to conventional radiographs of the suspicious areas, allowing morphologic study of regions with altered metabolism.

Salivary scan: There is a substantial difference between salivary gland scanning and contrast sialography, the conventional radiographic technique most frequently used to examine the major salivary glands. A sialogram is primarily an anatomic study using conventional contrast radiography techniques while a salivary gland scan is primarily a functional study using a tissue specific radioactive scanner. The techniques complement each other significantly and, when used together, render more complete information on the salivary glands than either technique used alone. When used together the scan should be done first as sialography causes a mild diffuse inflammation of the gland, which may cause increased uptake of 99m TcO_4^-, leading to spurious scan results.

Advantages

- Target tissue function is investigated.

- All similar target tissue can be examined during one investigation, e.g. the whole skeleton can be imaged during one bone scan.
- Computer analysis and enhancement of results is available.

Disadvantages

- Image resolution is poor – often only minimal information is obtained on target tissue anatomy.
- The radiation dose to the whole body can be relatively high.
- Images are not usually disease specific.
- Some investigations take several hours.
- Facilities are not widely available.

Diagnostic Ultrasound (Fig. 14.10)

Principle

As sound passes through any material, it encounters a certain level of impedance referred to as an 'acoustic impedance'. As sound passes from tissues of one sound acoustic impedance to another, some of it is reflected, some of it continues to penetrate and some energy is transferred to the particles of the medium as vibrational energy.

Fig. 14.10: Ultrasound of right submandibular gland, with a hyper echoic area—calculus?

The greater the difference in acoustic impedance of the tissue, the greater is the sound reflected. This reflected sound (or echo) is picked up by the transducer and converted into electric impulses and finally displayed on the screen.

By definition, ultrasound has a periodicity greater that 20 kHz. Diagnostic ultrasonography (sonography), the clinical application of ultrasound, uses vibratory frequencies in the range of 1 to 20 MHz.

Ultrasound signals are produced and detected by certain type of crystals (quartz, piezoelectric crystal) which are present in the transducer. These crystals change their shape when subjected to an electrical voltage. When the voltage is removed, the crystal returns to its former shape. The oscillations or vibrations that occur during this interval produce a short pulse of sound. The process works in the reverse also.

Scanners used for sonography generate electrical impulses that are converted into ultra-high-frequency sound waves by the transducer which are transmitted into the tissues being examined.

The ultrasound beam passes through or interacts with tissues of different acoustic impedance, it is attenuated by a combination of absorption, reflection, refraction and diffusion. Sonic waves that are reflected back (echo) towards the transducer cause a change in the thickness of the pieozelectric crystal, which in turn produces an electrical signal that is amplified, processed and ultimately displayed as an image on the monitor. In this system the transducer serves as both a transmitter and a receiver. Current techniques permit echoes to be processed at a sufficiently rapid rate to allow perception of motion; this is referred to as real time imaging.

The fraction of the beam that is reflected back to the transducer depends on the acoustic impedance of the tissue, which is a product of its density and the beam's angle of incidence. Because of its acoustic impedance, a tissue has a characteristic internal echo pattern. Thus, changes in echo pattern can delineate different tissues, but they can also be correlated with pathological changes in a tissue.

A-scan- is produced with the modulation of amplitude, the image appears as spikes extending towards the baseline. The height of each tracing is related to the intensity of each echo. A-scan shows the relationship between amplitude and depth, and are used for measuring the distances between boundaries of tissues with different acoustic properties. A-scan is used to distinguish between cystic and solid lesions and to measure the dimensions of structures such as the eye. It may be used to identify the location of the root apex.

B-scan- is displayed by brightness modulation, instead of a spike, a spot of variable brightness is produced on the cathode ray tube. There are two types of B-scans:

- Time position scan, which is more useful for the evaluation of dynamic structures, including components of the cardiovascular system.
- The compound B-scan, this helps to produce a two dimensional image of the region under examination. It is useful for the evaluation of soft tissue swellings such as those which may be encountered in a salivary gland or thyroid.

Continuous ultrasound – here the same change in frequency occurs with echoes that are coming from a moving interface within the body. Here two transducers are used, one to produce the sound and the other for the reception of the echo. This is useful for detecting heart sounds and for examining patterns of flow in blood vessels.

Clinical Applications

- Examination of the thyroid gland and the parathyroid glands and lymph nodes.
- Examination of extra cranial vessels of the neck, as a screening process to detect atheromatous plaques in the carotid artery, carotid artery aneursyms, venous thrombosis, stenosis and tumors of the carotid sheath.
- Examination of the parotid glands. It helps to differentiate between cystic and solid lesions, localize lesions for biopsy, locate calculus in the ducts or parenchyma of the gland.
- Examination of congenital inflammatory and neoplastic neck masses.
- To detect fractures of the orbital wall and accompanying soft tissue.
- Assessment of ventricular systems in babies by imaging through the open fontanelles.

Available data suggests that the benefits associated with ultrasound diagnosis outweigh any known risks.

It is now regarded as the investigation of choice for differentiating between solid and cystic lesions.

Advantages

- Sound waves are not ionizing radiations.
- There are no known harmful effects to any tissues at the energies and doses currently used in diagnostic ultrasound.
- Shows good differentiation between soft tissues.
- Technique is widely available and inexpensive.

Disadvantages

- Ultrasound has limited use in head and neck region because sound waves are absorbed by bone.
- Technique is very operator dependent.
- Images can be difficult to interpret for inexperienced operators because image resolution is often poor.

Arthrography (Figs 14.11A and B)

Arthrography of the TM joint is basically a method that will supply information on soft tissue state of the TM joint, especially the integrity and position of the disk and its posterior attachment. It also provides evidence of internal disk derangement or disk perforation.

This examination is most helpful in diagnosis of those cases in which little or no bony damage is evident on pre-arthrographic tomograms and in which clinical evidence (e.g. joint clicking or popping, painful limitation of opening or joint locking) suggests derangement of the disk.

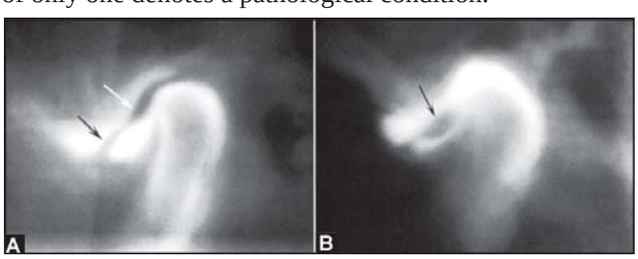
It also helps in differentiating disk derangement from other non bony problems such as capsulitis, myofascitis and myofacial pain dysfunction syndrome.

TM joint arthrography is performed by catheterizing the upper and lower joint spaces and injecting 0.5 to 1 ml of radiographic contrast media first into the lower space and then into the upper space. The most commonly used contrast media are iodine compounds.

A series of radiographs are taken following joint space opacification with the jaws closed and in graded stages of opening.

The disk appears as a radiolucent void between two opaque areas of contrast media because there is no known normal situation where a communication exists between the superior and inferior joint spaces.

Opacification of both the joint spaces following injection of only one denotes a pathological condition.



Figs 14.11A and B: Arthrographs in which both the lower and upper joint spaces have been injected with contrast media (spaces appear white) that highlights the disk (black). In both images the anterior aspect of the patient is on the left side of the image. In **A.** The posterior band (white arrow) and the anterior band (black arrow) are evident. **B.** Reveals a disk with an enlarged posterior band

Indications

- Long standing TMJ pain dysfunction unresponsive to simple treatments
- Persistent history of locking
- Limited opening of unknown etiology.

Diagnostic Information Provided

- Dynamic information on the position of the joint components and disk as they move in relation to one another.
- Static images of the joint components with the mouth closed and with the mouth open. Any anterior or anteromedial displacement of the disk can be observed.
- The integrity of the disk, i.e. presence of any perforations.

Limitations and Disadvantages of Arthrography

- Very painful.
- Not indicated when the patient is hypersensitive to iodine or the contrast medium.
- Iodine may bring about fibrosis.
- Very strict asepsis has to be maintained.
- Capsule may rupture if too much contrast media is injected.
- Contraindicated in acute joint infection.

Arthroscopy

Arthroscopy of the TM joint is a procedure where direct visualization of the internal joint structure can be done.

This aids in doing surgical procedures and biopsy procedures, which may be performed under visual control.

Advantages

- Safe procedure.
- Direct visualization yields information not achievable by other techniques.
- Minimal postoperative complications.
- Color change in inflammed tissues is clearly seen.
- Biopsy and surgical procedures can be easily visualized.
- It allows certain interventional procedures to be performed
  - Washing out the joint with saline
  - Introduction of steroids directly into the joint
  - Division of adhesions
  - Removal of loose bodies from within the joint

Arthroscopy is usually considered as the last line of investigation before full surgical exploration of the joint is carried out.

Xeroradiography (Figs 14.12A to D)

This method is based on an electrostatic process similar to that used for xeroxing. There are several features of xeroradiography that make it an attractive imaging system in specific diagnostic situations, like:

- Pronounced edge enhancement.
- High contrast.
- A choice of positive and negative displays.
- Good detail.
- Wide latitude.

And it does not require silver halide containing films such as those commonly used for conventional radiography.

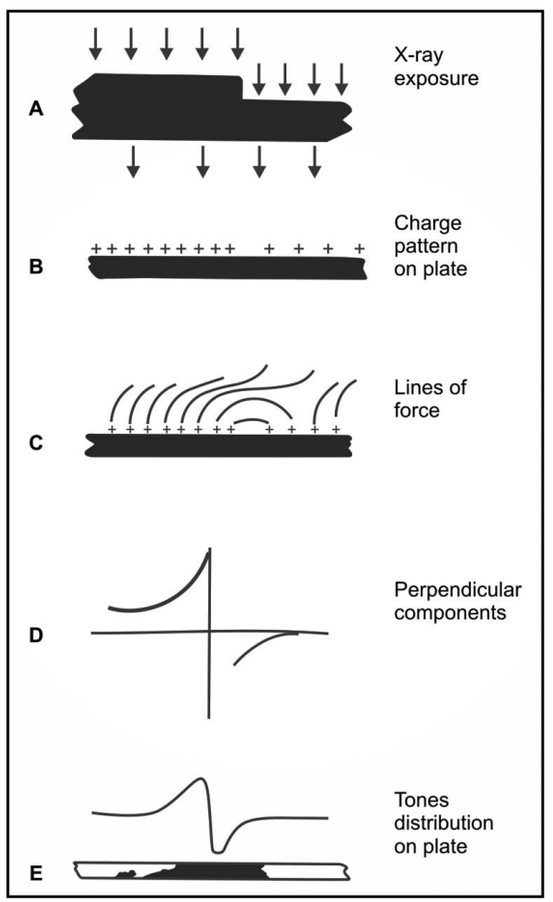


Fig. 14.12A: A. An X-ray beam passing through an object is differentially attenuated according to the absorption characteristics of the object. **B.** The distribution of transmitted X-ray photons alters the charge pattern on a xerox plate. **C.** Lines of force are produced as a result of the difference in charge densities on the plate surface. **D.** These lines of force have perpendicular components. **E.** These components affect the distribution of toner particles on the plate

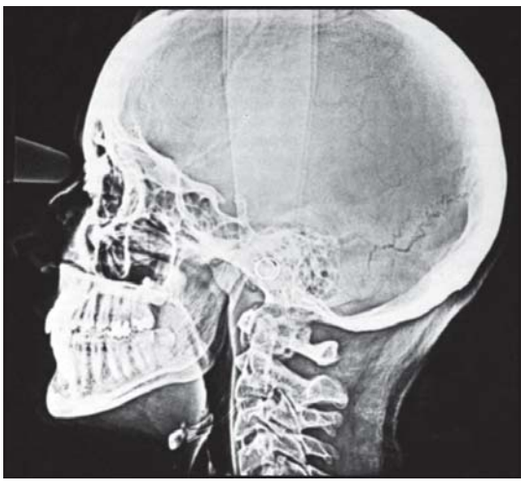


Fig. 14.12B: In this cephalometric image, the most dense structures are light and the least dense structures are dark. The visibility of both soft and bony structures in a single radiograph illustrates the wide latitude of the xeroradiographic process

There are two systems in xeroradiography;

1. The Medical 125 System
2. The Dental 110 System.

Conventional X-ray source is used in the production of xeroradiographs. The film, however is replaced by a selenium-coated photoreceptor (Xerox Plate), which has an uniformly distributed electrostatic charge. The charge is applied by a conditioner that also inserts the charged plate into a light-tight cassette. During an exposure, X-rays that penetrate a body part or object are absorbed by the surface of the selenium plate causing selective discharging. The distribution and the amount of discharge is related to the distribution and amount of radiation striking the xerox plate and, therefore, the information in the transmitted X-ray beam is left as a charged pattern on the plate. The pattern of electric charge, the latent image, is analogous to the latent image produced by the reduction of silver bromide molecules to free silver atoms in the sensitivity specks of a photographic emulsion.

The greatest amount of charge remains beneath the thickest part of the object where most radiation was absorbed. In areas where less absorption occurred, the penetrating radiation dissipates a greater amount of charge from the selenium surface. At the interfaces between the areas of greater and lesser absorption, the electrostatic forces are distorted. The resulting electric fields produce the same effect as the production of mach bands which occur at the boundaries of objects with different densities because of a phenomenon called lateral extinction which occurs in the retina.

The latent image is developed into a visible image. During development a cloud of charged powder particles of toner is exposed to the plate, and the powder particles are attracted to the charged pattern on the surface. The association between the toner and the plate is related to the distribution of charge. When the development is complete, the visible image is transferred to paper in a machine referred to as a developer.

The electric fields present during development result partly from the voltage applied to the back of the plate for the purpose of delivering toner particles and partly from the difference in the charge distribution in the latent image. Non uniformities exist at the boundaries between different charge

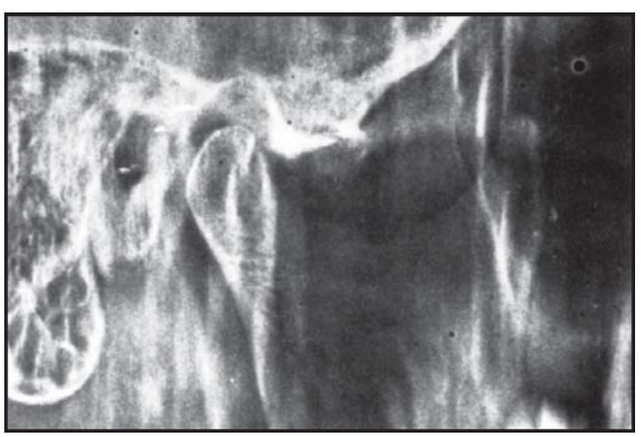


Fig. 14.12C: A thin section tomogram of a TMJ in the closed position. A discontinuity is noted at the anterior surface of the condyle

Fig. 14.12D: This thin section xerotomogram shows the same joint with mouth in an open position. The condyle is outside the fossa and slightly rotated

intensities and result in the deposition of more toner to the higher charged side of the boundary and less toner to the lower charged side. In the resulting image, the boundaries or edges are enhanced.

When a positive voltage is applied to the back of the Xerox plate during development, negative toner particles are attracted to the surface. In this mode, highly charged areas corresponding to the thickest or most dense parts of the body receive more toner than the discharged areas covered by thin or low density body parts. This results in a positive image in which the darkest area of the image correspond to the most dense parts of the anatomy.

Negative images can be produced by the application of a negative voltage to the back of the plate, which attracts positive toner particles to the surface. Positively charged particles are preferentially attracted to the discharged parts of the plate, which corresponds to the least dense parts of the body. In the final image, dense objects appear white or radiopaque, and less dense objects appear dark or radiolucent.

Xeroradiograph can be viewed in reflected or transmitted light. When the latent image is transferred from plate to paper, the original image is reversed 180° and is seen as a mirror image.

Uses

- Mammography.
- Cephalometry.
- Evaluation of bone lesions in the mandible.
- Sialography
- Study of variety of dental and non dental structures.
- TM joint tomography.

The dental xeroradiograph system has a different physical design. The image receptor plates are the size No. 1 and 2 films and fit into the patient's mouth. The image receptors are charged and processed into a final permanent image in a single piece of equipment. To make an image, the photo receptor is charged at the output station. It is then put intraorally, exposed, and returned to the input station. The plate passes over a toner station, where charged toner particles suspended in a liquid vehicle are deposited on the plate to develop the image. Next the plate is dried to remove the liquid vehicle. The image is recovered from the plate by using a clear adhesive transfer station. The adhesive tape is brought into contact with the plate and pulls off all the toner particles. The image is protected by applying the adhesive with the image to a translucent backing strip.

Indications in Head and Neck Region

- Periodontal and periapical assessment to show good bony details.
- Cephalometric radiography to show the required hard and soft tissue landmarks on one film.
- Sialography to show fine duct structure.
- Assessment of soft tissue shadows in the pharynx and larynx.

Advantages

- High contrast.
- Greater ability to resolve fine structures.
- They require 1/3rd the exposure of conventional radiographs.
- Easy to use.
- Produces permanent dry images for viewing in about 20 seconds after the exposed photoreceptor is returned to the machine.
- Image is easily reversible.
- For diagnostic purpose, as this method gives excellent definition of thin, fine structures due to edge enhancement,
  i. Height of alveolar crest better visualized.
  ii. Caries seen more readily.
  iii. Useful in endodontics.
  iv. Detection of cancer.
  v. Imaging biomaterials.

Disadvantages

- Edge enhancement artifacts.
- Processors are expensive.
- High radiation dose needed for extraoral techniques.

Sialography (Figs 14.13A and B)

Is a radiographic procedure that is a useful diagnostic adjunct for the detection and monitoring of salivary gland disease. This technique is used to examine the ductal and acinar systems of the major salivary glands. The glands are cannulated and filled with a radiopaque contrast agent to make them visible on the radiographs. The procedure reveals the location and integrity of the salivary glands, and indicates the presence of diseases that change the internal architecture.

Indications

i. Detection of calculus or calculi or foreign bodies, whether these are radiopaque or radiolucent.

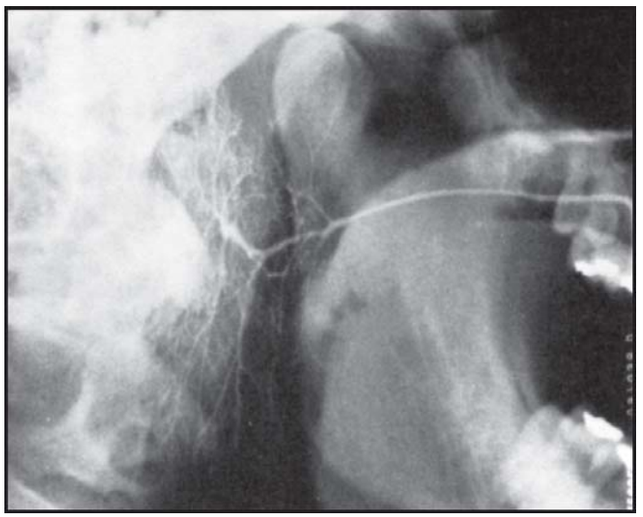


Fig. 14.13A: Injection of the opaque material through the opening of the parotid duct demonstrated the absence of an obstruction

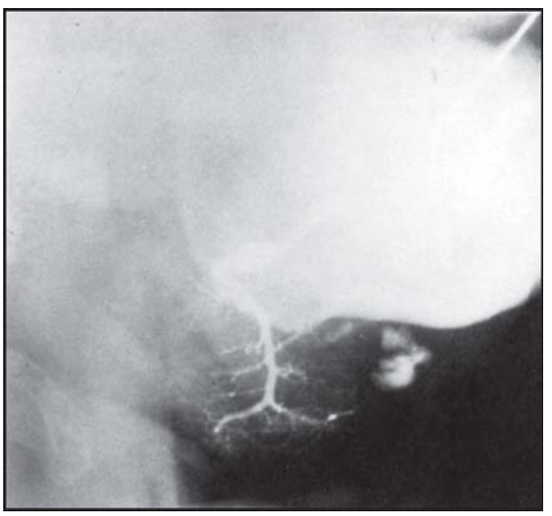


Fig. 14.13B: Radiographs are two-dimensional representations of three-dimensional objects. Slight rotation of the patient's head demonstrates that the calcification lies well beyond the boundary of the gland, which other wise could have appeared as calcifications in the submandibular region are superimposed over the gland

ii. Determination of the extent of destruction of the gland secondary to obstructing calculi or foreign bodies. This will aid in deciding whether a total excision of the gland or a simple lithotomy should be performed.
iii. Detection and portrayal of fistulae, diverticula or strictures.
iv. Determination and diagnosis of recurrent swellings and inflammatory processes.
v. Demonstration of a tumor and the determination of its location, size and origin, whether the radiograph suggests a benign or a malignant lesion.
vi. Selection of a site for biopsy.
vii. Outline of the plane of the facial nerve as a guide in planning a biopsy or dissection.
viii. Detection of residual stone or stones, residual tumor, fistula or stenosis; or retention cysts following simple lithotomy or other surgical procedures.
ix. Sialography has also been recognized as a therapeutic procedure because:
    - The dilatation of the ductal system produced during the study may aid in the drainage of the ductal debris.
    - The therapeutic effect produced by the iodinated contrast media when injected into the ductal system has also been seen.

Contraindications

i. Patient with a known sensitivity to iodine compounds and patients who have experienced severe asthmatic attacks or anaphylaxis following use of iodine compounds in a prior radiologic examination, should not be considered subjects for this technique. A history of nausea and vomiting following the intravenous injection of contrast media is not considered a contraindication.
ii. The use of sialography during a period of acute inflammation of the salivary system is contraindicated. During this period the ductal epithelium may be disrupted, and escape of the contrast medium from the ductal system into the parenchyma can produce severe foreign body reaction, accompanied by severe pain. This is specially true when the oily contrast medium is used. Foreign body reaction following the use of water soluble media has not been reported.
iii. The administration and retention of the iodinated contrast material may interfere with subsequent thyroid function tests, such function studies if required, should be done prior the sialography procedure.

Contrast Media

An ideal sialographic contrast media should have the following characteristics:

i. Physiological properties similar to that of saliva.
ii. Miscibility with saliva.
iii. Absence of local or systemic toxicity.
iv. Pharmacological inertness.

v. Satisfactory opacification.
vi. Low surface tension and low viscosity to allow filling of fine components of the ductal system.
vii. Easy elimination, but should be durable for sufficient time so as to permit time for satisfactory radiographs.
viii. Residual contrast media should be absorbed by the salivary gland and detoxified by the liver or excreted by the kidney.

Two Types of Contrast Media are Available

i. Water soluble media	*ii. Fat soluble media (Oil Based)*
a. These are principally iodinated benzene or pyridone derivatives.	a. There are two types of fat soluble contrast media. 1. Iodized Oil. 2. Water Insoluble Organic Iodine Compounds.
b. These compounds have a low viscosity, less surface tension and are more miscible with the salivary secretions.	b. These compounds are more viscous have more surface tension and are less miscible with the salivary secretions.
c. These physical characterstics permit filling of the finer ductal system under lower pressure and facilitate prompt drainage.	c. It requires a higher injection pressure than that of the water soluble media, to visualize finer ducts. Oil based media is poorly elimi nated and causes ductal obstruction.
d. Causes less pain or discomfort, with no granulomatous reaction, in the glands.	d. Usually accompanied with pain and a lot of discomfort. Extravasation of the fat soluble media can produce severe foreign body reaction with focal necrosis of the parenchyma and stroma.
e. Opacification of the water based media is not as good as that of oil media.	e. The fat soluble contrast media on the whole produces a satisfactory degree of opacification. This a an excellent media if the ductal systems under examination are intact.
f. The excretion of the contrast media is very rapid.	f. The excretion of the contrast media is slow and gives adequate time to carry out the various radiographic procedures.
g. Hydropaque and Renografin are the available water soluble contrast media.	g. Ethidol is the available fat soluble contrast media.

Procedure

Before starting with the procedure, collect all data sheets containing pertinent and clinical data including patient's name, age and hospital identifying data, the chief complaint, the physical findings and clinical impression, previous history of allergy, prior radiologic study and reports, and the volume and type of contrast media previously used.

Before the initiation of the examination and injection of the contrast media, the patient is instructed to raise his right hand if he experiences any discomfort during the procedure. The amount of contrast media to be injected should be governed by the production of pain.

This is divided into three main steps:

1. The preliminary plain film evaluation.
2. The injection or filling phase.

Equipment required;

- Polyethylene tubing with a special blunt end metallic tip with
  - side hole for parotid gland.
  - end terminal hole for submandibular gland.
- 5 or 10 cc syringe.
- Lacrimal dilators.
- Contrast media.
- Sialagogue, like 5 lemon slices or lemon extract or chewing gum.

The parotid orifice is located at the base of the papilla in the buccal mucosa adjacent to the first or second molar. The area over the mucosa where the duct orifice is expected to be located should be dried with a small sponge. If the gland has some degree of function, a drop of saliva can be expressed by applying gentle pressure to the skin over the main parotid areas, thus identifying the location of the orifice.

The submandibular excretory duct orifice is situated on the summit of the small papilla at the side of the lingual frenum, but care should be taken to differentiate it from the sublingual gland orifices in the same region.

After the appropriate orifice has been identified, the duct can be explored with the lacrimal probe.

In case of the submandibular gland, the probe should pass through the length of the floor of the mouth to the level of the posterior border of the mylohyoid muscle, a penetration of about 5 cm.

Because of the tortuous course of the parotid duct, the cheek has to be turned outward before the probe is inserted into the duct. The eversion of the cheek will help reduce the possibility of penetrating the duct at one of the sharp angles in its course.

In both the parotid and submandibular ducts, the probe should slide easily back and forth and also rotate freely without dragging.

When the duct orifice has been adequately sized and enlarged, the sialographic cannula is inserted into the duct so that the tissue stop presses firmly into the orifice to prevent dye reflux. The cannula may be held in place by taping the tubing to the face or by having the patient bite on the tubing wrapped in sponge.

After insertion of the cannula, the radiographic dye is slowly introduced into the duct. The amount of dye to be placed in the gland for adequate filling varies from patient to patient and depends on the condition of the gland.

The amount used is best determined by fluoroscopic observation; the patient should be instructed to inform the operator when the gland area feels tight or full.

Appropriate volumes of dye required vary from 0.76 to 1.00 ml. For the parotid glands, and 0.0 to 0.75 ml for submandibular glands. The cardinal rule is that the injection should be stopped when the gland is full, if the dye is extravasated, or when the patient experiences mild discomfort.

Radiographic Projections

The filming procedure is carried out with the patient in the supine position. All dentures should be removed. Often several films are obtained during the injection in order to monitor the filling phase and degree of filling. Because geometrical artifacts are introduced by all techniques, it is important to use the same procedure consistently.

The lateral oblique projection and/or mandibular occlusal view is used to delineate the submandibular gland. In the lateral oblique the duct pattern is not distorted and a sialolith is seen well on the occlusal view.

The AP view of both glands demonstrates the medial and lateral gland structures. In case of the parotid gland the patient should be asked to keep the mouth open.

The panoramic projection may also be taken. This is helpful in studying erosion of bone or destruction of the mandible, in case of salivary tumors.

3. The evacuation (fat soluble medium) or the parenchymal phase (water soluble medium).

After the final sialographic views have been made, the cannula should be removed from the duct orifice. The patient is instructed to chew gum or the lemon slice and then asked to rinse. This is done to stimulate the gland and cause excretion of the dye.

Lateral jaw, lateral oblique or AP radiographs should be made 5 minutes after removal of the cannula. They provide the information about the excretory function of the gland.

Normal salivary gland will excrete 100 percent of the contrast dye within 5 minutes after removal of the cannula.

Additional views which may be taken to study special features are:

1. Reverse basilar view to demonstrate the deep portion of the parotid.
2. A film made with the cheek in the blow-out position in the anteroposterior view to demonstrate the superficial portion of the course of the Stenson's duct of the parotid gland.
3. Occlusal view for demonstration of the distal submandibular gland's Whartons duct.
4. Filming of the filling phase with the mouth open will reduce superimposition of the mandible on the parotid gland.
5. Stereoscopic studies are invaluable for the study of the spatial relationships of the gland and the duct.
6. Subtraction views are of great value in the delineation of the finer ducts and of the sublingual ductal system.
7. Plesioradiography is a technique in which a small X-ray tube is placed in contact with the facial soft tissues contralateral to the gland being examined in an attempt to eliminate the obscuring overlying bony structures.

Implant Imaging (Fig. 14.14A)

The reliability of contemporary implant system derive, in part, from the increasing sophisticated imaging techniques used in all phases of implant treatment.These imaging modalities contribute information for every stage of the treatment, extending from presurgical diagnosis and treatment planning, through surgical placement and post operative assessement of the implant, into the prosthetic restoration and long-term surveillance phase.

The various imaging techniques which can be applied to various phases of surgical and restorative procedures may be analog or digital Periapical, Panoramic, Occlusal, Cephalometric, Tomography, Computed Tomography, MRI Interactive Computed Tomography and Two Dimensional or Three Dimensional (computed tomography, MRI, ICT). (Tables 14.1 and 14.2).

In general implant imaging requirements can be divided into three phases:

Pre prosthetic Implant Imaging – this includes all past radiographic examinations along with the present radiographic examinations to help and assist to obtain all surgical and prosthetic information to determine the quantity, quality and angulation of bone, the relationship of critical

Table 14.1: Commonly used radiographic procedures with time intervals for treatment planning and assessment of dental implants

Stage of treatment	*Time (Months)*	*Radiographic procedures*
Treatment planning	–1	PA, pan, tomo, CT, ceph
Surgery (placement)	0	PA, pan, tomo, CT, ceph for correction of problems
Healing	0 to 3	PA, pan, tomo, CT, ceph for correction of problems
Remodeling	4 to 12	PA, pan
Maintenance (without problems)	13+	PA, pan, (follow up approximately every 3 years)
Complications	Anytime	PA, pan, CT (as indicated)

PA = periapical; pan = panoramic radiography; tomo = conventional tomography; CT = reformated computed tomography; cep = lateral or lateral oblique cephalometric radiography

structures to the prospective implant sites, and the presence and absence of disease at the proposed surgery sites.

Surgical and Interventional Implant Imaging- this is focussed on assisting in the surgical and prosthetic intervention of the patient. The objective is to evaluate the surgery sites during and immediately after surgery and in assisting in orientation and optimal positioning of the implants, to evaluate the healing and the integration phase of the dental implant surgery, and ensure abutment position and prosthesis fabrication are correct.

Postprosthetic Implant Imaging- this commences after the prosthetic placement and continues as long as the implants remain in the jaws. The objective is to evaluate long-term maintenance of the implant's rigid fixation and function, including the crestal bone levels around each implant, and to evaluate the implant complex (Table 14.3).

The use of imaging stents helps relate the radiographic image and its information to a precise anatomical location or potential surgical site. In case of conventional and computed tomography, an imaging stent also facilitates

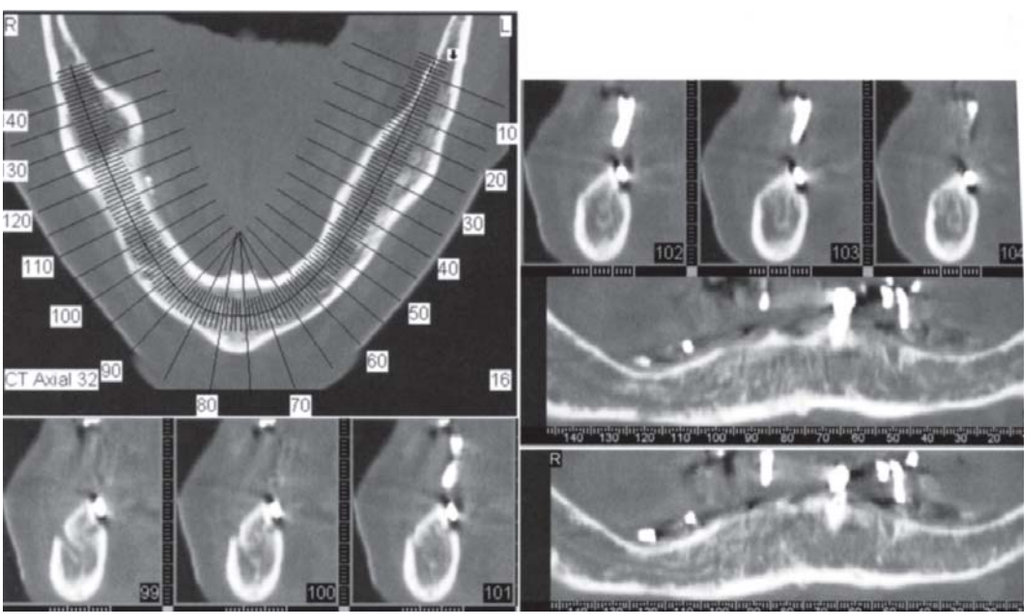


Fig. 14.14A: Programmed Dental CT. The radiologist identifies curvature of the mandible, which programs the CT work station to create reformated cross-sectional and curved plane images. Axial view of mandibular alveolus with curvature of the mandible defined and location of the derived cross-sectional and curved plane images identified. Images 99 to 102 are cross-sectional images and that are referred to as axial and curved plane images. Images 8 and 9 are curved plane images that are referred to as the axial and cross-sectional images. Gutta percha radiopaque cylinders identify prospective implant positions

Table 14.2: Summary of techniques for implant imaging

Imaging technique	*Applications*	*Advantages*	*Disadvantages*
Intraoral periapical radiography	S, M, E, A	Readily available High image definition Minimal distortion Least cost and radiation exposure	Limited imaging area No facial lingual dimension Limited reproducibility Image elongation and foreshortening
Intraoral occlusal radiography	S, M, A	Readily available High image definition Cross facial-lingual dimension Relatively large imaging area Least cost and radiation exposure	No detailed facial-lingual dimension Limited reproducibility Not as applicable for maxilla Image superimposition
Panoramic radiography	S, M, E, A	Readily available Large imaging area Minimal cost and radiation exposure	No facial-lingual dimension Image distortion Technique errors common Inconsistent magnification Geometric distortion
Conventional tomography	S, M, E, A	Minimal superimposition Facial-lingual dimension Uniform magnification Measurements accurate within about 1 mm Moderate cost	Less image definition than plain films Somewhat limited availability Special training for interpretation Sensitive to technique errors Greater radiation exposure for multiple sites
Reformated computed tomography	M, E, A	Simulates placement with software Allows evaluation of all possible sites No superimposition Uniform magnification Measurements accurate within about 1 mm estimates internal bone density Simulates placement with software	Limited availability Sensitive to technique errors Metallic image artifacts Special training for interpretation Higher cost and radiation exposure Volume averaging contributes to measurement error

S = single implant, M = multiple implants (2 to 5), E = edentulous (6+), A = augumentation

Table 14.3: Radiographic signs associated with failing endosseous implants

Radiographic appearance	*Clinical implications*
Thin radiolucent area that closely follows the entire outline of the implant	Failure of the implant to integrate with the adjoining bone
Crestal bone loss around the coronal portion of the implant	Osteitis resulting from poor plaque control, adverse loading, or both
Apical migration of alveolar bone on one side of the implant	Nonaxial loading resulting from improper angulation of the implant
Widening of the periodontal ligament space of the nearest natural (tooth) abutment	Poor stress distribution resulting from biomechanical inadequate prosthesis implant system
Fracture of the implant fixture	Unfavorable stress distribution during function

association of the individual image slice to an anatomical location in the scout films. The intended image sites are identified by markers made of radiopaque spheres or rods metal, composite resin or gutta percha (Fig. 14.14B).

Various interactive software packages have also been developed to allow presurgical simulation of implant orientation and placement on a computer screen.

CAD CAM Stereotactic Surgical Templates; can be produced from CT examinations that have used interactive CT to develop a three-dimensional treatment plan for the patient of the position and orientation of dental implants. Anatomically accurate three-dimensional models of the patient's alveolar anatomy can be produced by a number of CAD CAM and rapid protyping procedures.

MRI is used in implants as a secondary imaging technique when the primary imaging techniques such as complex tomography, CT or ICT fail.

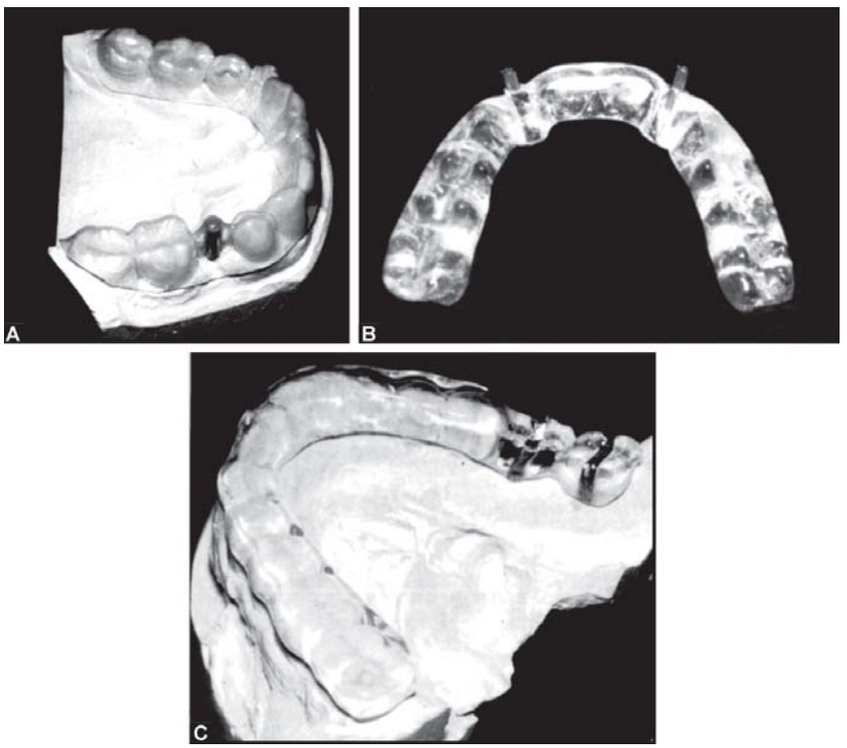


Fig. 14.14B: Three examples of imaging stents. **A.** Vacuum formed imaging stent with a metal rod to indicate desired axis of insertion. **B.** Processed stent with metal cylinders marking the image sites. This can also be used as a surgical stent by inserting the guide bur through the cylinders. **C.** Processed stent with insertion axis markers, along with a radiopaque strip outlining the buccal and lingual contours of the planned restoration. This provides an image of the emergence profile of the restored implant. This stent can also be used as a surgical guide

Radiographic Image Storage via Laser Optical Technology

The laser optical disk technology uses a laser diode as a light source for recording and play back of data. The laser optical disk memory recording can be used for storing, retrieving and displaying dental and medical radiographs.

Advantages

- Zoom magnification.
- Brightness and contrast can be adjusted.
- Image enhancement capability.

BIBLIOGRAPHY

1. Allan B Reskin. Advances in Oral Radiology, PSG Publishing Co. 1980.
2. Goaz PW, White SC. Extra Oral Radiographic Examinations In Oral Radiology, Principles and Interpretationn, 3rd ed. St. Louis, Mosby- year book, 1994; 339
3. Langland OE, Langlais RP. Special Radiographic Techniques. In Principles of Dental Imaging Baltimore, Williams and Williams, 1997; 265-87.
4. Misch EC, Rivcos LT. Contemporary Implant Dentistry, (2nd Ed,) Part I Ch.6. Diagnostic Imaging and Techniques, 1999;73-89.
5. Razmns JF, Williamson GF. An overview of oral and maxillofacial imaging. In current Oral maxillofacial imaging, Philadelphia, WB Saunders, 1996; 1-22.

15

Digital Radiography

The advent of digital imaging has revolutionized radiology. The purpose of digital radiography is to generate images that can be used in the diagnosis and assessment of dental disease. It is used:

- To detect lesions, diseases and conditions of the teeth and surrounding structures
- To confirm or classify suspected disease
- To provide the information during dental procedures (e.g. root canal therapy instrumentation and surgical placement of implants)
- To evaluate growth and development
- To illustrate changes secondary to caries, periodontal disease or trauma
- To document the condition of a patient at a specific point of time.

The term digital radiography refers to a method of capturing a radiographic image using a sensor, breaking it into electronic pieces and presenting and storing the image using a computer. This system is not limited to intraoral images; panoramic and cephalometric images may also be obtained.

Radiation Exposure

Digital imaging requires less X-radiation than conventional radiography, because the sensor is more sensitive to X-rays than conventional film. Exposure time for digital radiography are 50 to 80 percent less than that required for conventional radiography using E-speed film, and thus the absorbed dose to the patient is much lower.

Three Methods to Obtain a Digital Image Currently Exist

- *Direct Digital Imaging*: Here a sensor is placed in the patient's mouth and exposed to radiation. The sensor captures the radiographic image and then transmits the image to a computer monitor, and within seconds the image appears on the computer screen.
- *Indirect Digital Imaging*: In this method an existing X-ray film is digitized using a CCD camera, which scans the image, digitizes or converts the image and then displays it on the computer monitor.
- *Storage Phosphor Imaging*: It is a wireless digital radiography system. A reusable imaging plate coated with phosphors is used. These plates are flexible and fit into the mouth. The storage phosphor imaging records diagnostic data on the plates following exposure to the X-ray source and uses a high-speed scanner to convert the information to electronic files which can be displayed on the computer screen.

Equipment

The essential components of a direct imaging system include:

A. X-radiation source
B. Intraoral sensor
C. Digital image display

A. *X-radiation source*: Most digital radiography systems use a conventional X-ray unit as the radiation source. The X-ray unit timer has to be adapted to allow exposures in a time frame of 1/100th of a second. A standard X-ray unit that is adapted for digital radiography can still be functional for conventional radiography.
B. *Intraoral sensor*: Is used instead of the intraoral film. It is a small detector that is placed in the mouth of the patient and used to capture the radiographic image.

Analog Versus Digital

The term in digital imaging refers to the numeric format of the image content as well as its discreteness. Conventional films may be considered as an analog medium in which differences in the size and distribution of black metallic silver result in a continuous density spectrum. Digital images are numeric and discrete in two ways:

- In terms of the spatial distribution of the picture elements (pixels).
- In terms of different shades of gray of each pixel.

A digital image consists of a number of collection of individual pixels organized in a matrix of rows and columns. Each pixel has a row and a column coordinate that uniquely identifies its location in the matrix.

The electrons that make up the electronic detector can be visualized as being divided into an arrangement of blocks or picture elements known as pixels. A pixel is a small box or "well" into which the electrons produced by the X-ray exposure are deposited. A pixel is the digital equivalent of a silver crystal used in conventional radiography. As opposed to film emulsion that contains a random arrangement of silver crystals, a pixel is structured in an ordered arrangement.

The X-ray photons that come into contact with the electronic device cause electrons to be released from the silicon and produce a corresponding electronic charge. Consequently each pixel arrangement, or electron potential well contains an electronic charge proportional to the number of electrons that react within the well. Further more each electronic well corresponds to a specific area on the linked computer screen. When X-rays activate electrons and produce such electronic charges, an electronic latent image is produced; the latent image is then transmitted and stored in the computer and can be converted to a visible image on screen or printed on paper.

The formation of a digital image requires several steps, beginning with the analog processes. At each pixel of an electronic detector, the absorption of X-rays generates a small voltage. At each pixel the voltage can fluctuate between a minimum and maximum value and is therefore an analog signal.

Production of a digital image requires a process called analog-to-digital conversion (ADC). This consists of two steps:

- Sampling, that is a small range of voltage values are grouped together as a single value
- Quantization, that is that every sampled signal is assigned a value.

These values are stored in the computer and represent the image, which is done by the computer organizing the pixels in their proper locations and giving them a shade of gray that corresponds to the number that was assigned during the quantization step.

Digital Detector Characteristics

- Contrast resolution: is the ability to distinguish different densities in a radiographic image. This is the function of the interaction of the attenuation characteristics of the tissues that are being imaged, the capacity of the image receptors to distinguish differences in the numbers of X-ray photons coming from different areas of the subject, the ability of the computer to display or other output to portray differences in density, and the ability of the observer to recognize those differences.
- Spatial resolution: is the capacity for distinguishing fine detail. The theoretical limit of resolution is a function of picture element (pixel) size for the digital imaging systems. Resolution is often measured and reported in units of line pairs per millimeter. A line and it's associated space are called a line pair (lp). At least two pixels are required to resolve a line pair, one for the line and one for the space.
- Detector latitude: is the ability of an imaging receptor to capture a range of X-ray exposures is termed latitude. The latitude of CCD and CMOS detectors is similar to film and can be extended with digital enhancement of contrast and brightness. Photostimulable phosphor receptors enjoy larger latitudes and have a linear response to five orders of magnitude of X-ray exposure.
- Detector sensitivity: is the ability to respond to small amounts of radiation. Useful sensitivity of digital receptors is affected by a number of factors including detector efficiency, pixel size and system noise. High resolution CCD and CMOS systems achieve less dose reduction than lower resolution PSP systems.

The Different Type of Sensors or Digital Detectors Currently Available are; (Fig. 15.1) (Tables 15.1 and 15.2)

1. *Charged Couple Device (CCD)*: This is a solid state detector that contains a thin wafer of silicon chip with an electronic circuit embedded in it. The silicon chip is sensitive to X-rays or light. The silicon matrix and its associated readout and amplifying electronics are enclosed with a plastic housing to protect them from the oral environment.

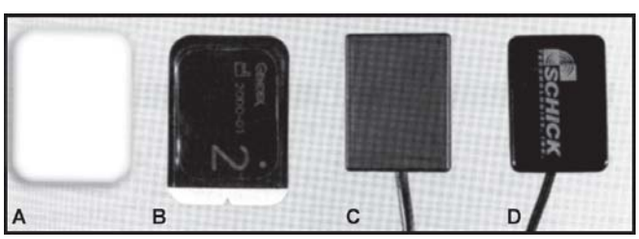


Fig. 15.1: A. Kodak #2 film, **B.** Gendex #2 PSP plate, **C.** Gendex #2 CCD sensor, **D.** Schick #2 CMOS sensor

Table 15.1: Clinical comparison of intraoral imaging alternatives

Imaging step	*Film*	*CCD/CMOS*	*PSP*
Receptor preparation	None	1. Place protective plastic sleeve over receptor 2. Receptor must be connected to computer and patient identifying information entered for acquisition/archiving software	1. "Erase" plates 2. Package plates in protective plastic envelope
Receptor placement	1. Numerous generic film holding devices are available 2. Film may be bent to accommodate anatomy	1. Specialized receptor holder specific for manufacturer's receptor may limit options 2. Receptor inflexibility and bulk limit placement options 3. Receptor cable must be carefully routed out of patient mouth 4. Patient discomfort more likely than with film or PSP	1. Many receptor holders used for film may be adapted for PSP plates 2. Bending of receptor may irreversibly damage it
Exposure	Simple exposure	Computer must be activated prior to exposure	Simple exposure
Processing	1. Dark, light-safe environment in form of darkroom or daylight loader required 2. Processor chemistry must be prepared or replenished 3. Chemical temperature must be warmed, or processing time must be adjusted to accommodate temperature 4. Films must be removed from wrapper; lead foil must be separated for recycling	Image acquisition and display is almost immediate	1. Dimly light environment desirable to prevent loss of image information 2. Processor must be programmed with patient and detector information so that images are identified, preprocessed, and stored properly 3. Protective wrapper must be removed from plates 4. Plates must be loaded on drum systems
Display preparation	1. Films may be placed in a variety of film mounts 2. Mounts must be labeled with patient identifying information	1. Software may be configured to place image in appropriate position in digital mount when exposures are made in a predetermined sequence; otherwise, images must be individually placed in mount 2. Images may need to be digitally rotated to achieve proper orientation	1. Images must be individually placed in mount 2. Images may need to be digitally rotated to achieve proper orientation
Display	1. A room with subdued lighting and a masked viewbox are optimal 2. Any light source (including the operatory window or ceiling light) will permit a quick evaluation of the image	Same considerations apply to all digital receptor types 1. A room with subdued lighting is optimal for interpretation activities 2. A computer and display with appropriate software are necessary; viewing is restricted to the location of the computer 3. Laptop computers increase flexibility of computer placement but may reduce display quality 4. Size of the display will restrict the numbers of images that may be viewed simultaneously; more time is required to open/close or expand/contract images when interpreting a series of images	
Image duplication	Quality of duplication is always inferior to original and is sometimes nondiagnostic	1. Electronic copies may be stored on a variety of media without loss of image quality 2. Output on film or paper is inferior and is often nondiagnostic unless appropriate combinations of expensive printers and papers or film are used	

Table 15.2: Comparison of physical properties of film, CCD, CMOS, and PSP receptors

Feature	*Technical comment*	*Clinical comment*
Spatial resolution	Intraoral systems: Film > CCD = CMOS > PSP Panoramic systems: Film CCD = PSP Cephalometric systems Film > CCD = PSP	The limits of resolution for digital systems are readily appreciated when magnifying these images. With magnification a "blocky" or "pixilated" appearance is evident. Resolution of panoramic systems is limited by mechanical motion to about 5lp/mm
Exposure latitude	PSP >> CCD = CMOS ≥ film	Because of the wide latitude of PSP and the automatic brightness and contrast "optimization" by image acquisition software, use of more X-ray exposure than is necessary is possible.
Receptor dimensions	For equivalent imaged area, Film = PSP < CCD = CMOS	The "active area" of CCD and CMOS receptors is smaller than the surface area because of other electronic components within the plastic housing
Time for image acquisition	CCD = CMOS << PSP = film	Rapid image acquisition may be important for endodontic procedures or during implant placement
Image quality	Subjective quality is best with film when carefully exposed and well processed	Digital and film imaging are not significantly different when used for common diagnostic tasks
Image adjustment/ processing	Improves appearance of digital images	Takes time; may not improve diagnostic performance
Cost	Initial costs of digital systems are greater than film. Subsequent costs vary greatly depending on receptor wear and tear or abuse.	Manufacturer's estimates of life expectancy of reusable receptors are perhaps overly optimistic.
Reliability	Mechanical problems affect digital PSP and film systems. Software reliability varies greatly among manufacturers. Changes in unrelated computer components and software can cause digital systems to malfunction	Digital systems fail when problems occur with receptors during image acquisition, or with computers during image processing, archiving, and display.
Image storage and retrieval	Data backup is critical for digital systems.	Films can be misfiled and lost or be damaged by poor storage conditions. Digital data can be lost as a result of failures in power supplies and/or storage media, as well as operator error.
Transmitting images to others	Rapidly done with digital images.	Facilitates communication between colleagues or with insurance companies.

Most detectors used may have:

a. Electronic cable or wire systems, that is a fiberoptic cable by which the sensor is attached to the computer and transfers the data to the ADC. The length varies from 8 to 35 feet, shorter the cable more limited the range of motion.
b. Wireless or cordless systems, where the imaging sensor a phosphor coated plate is not linked by a cable. The cable connection has been replaced with a microwave transmitter.

The detectors are available in varying active sensor areas which roughly correspond to the sizes of different intraoral film. The individual pixels in size varies from 20 microns to 70 microns. Consequently, the CCD may contain approximately 307,200 pixels and functions to sense transmitted light and translate it into an electronic message.

The CCD's are more sensitive to light than X-rays, and thus a layer of scintillating material (like Gadolinium oxybromide compounds) is coated directly or coupled to the surface by fiberoptics, increasing the X-ray absorption efficiency.

The silicon crystals are formed in a picture element (pixel) matrix. When exposed to radiation, the covalent

bonds between the silicon atoms are broken, producing electron hole pairs. The electrons are then attracted to the more positive potential in the device, where they create 'charge packets'. Each packet corresponds to one pixel. The charged pattern formed from the individual pixels in the matrix represents the latent image. The image is read by transferring each row of pixel charges from one pixel to the next in a 'bucket brigade' fashion. As the charge reaches the end of the row, it is transferred to a read out amplifier and transmitted as a voltage to the analog-to-digital converter located within or connected to the computer. Voltages from each pixel are sampled and assigned a numerical value representing a gray level.

2. *Complementary Metal Oxide Semiconductors (CMOS)*: These are silicon based semiconductors where the pixel is isolated from its neighboring pixels and is directly connected to the transistor. Like in the CCD the electron-hole pairs are generated within the pixel in proportion to the amount of X-ray energy absorbed. This charge is transferred to the transistor as a small voltage. The voltage in each transistor can be read separately by a frame grabber, and then stored and displayed as a digital gray value.

   This technology is commonly used in digital cameras and has been recently incorporated as a sensor in dental digital radiography. It is believed to give 25% more resolution and the chip is less expensive and offers greater durability than the CCD.
3. *Charge Injection Device (CID)*: is another sensor technology, structurally it is very much like the CCD, but in this case no computer is required to process the images. This system consists of a CID X-ray sensor, cord and plug that can be inserted into the light source on the camera platform, digital images are seen on the system monitor within seconds. The CID sensor uses the same docking platform as the intraoral camera. The image can be printed with a color video printer and saved as a computer file or onto a video desk recorder.
4. *Photostimulable Phosphor Plates (PSP)*: These absorb and store energy from X-rays and then release this energy as light (phosphorescence) when stimulated by other light of appropriate wavelength. The photo-stimulator phosphor used for radiographic imaging is Europiumdoped, barium fluorohalide. Barium in combination with iodine, chlorine, or bromine forms a crystal lattice. The addition of Europium creates imperfections in this lattice. When exposed to sufficiently energetic source of radiation, valence electrons in Europium can absorb energy and move into the conduction band. These electrons migrate to nearby halogen vacancies in the fluorohalide lattice and may become trapped there in a metastable state. While in this state the number of trapped electrons is proportional to X-ray exposure and represents a latent image. When stimulated by red light of around 600 nm, the barium fluorohalide releases trapped electrons to the conduction band. When an electron returns to the Europium ion, energy is released in the green spectrum between 300 and 500 nm. Fiberoptics conduct light from PSP plate to a photomultiplier tube, which converts light into electrical energy. A red filter at the photomultiplier tube selectively removes the stimulating light, and the remaining green light is detected and converted to a varying voltage. The variation in the voltage output from the photomultiplier tube corresponds to variations in stimulated light intensity from the latent image. The voltage signal is quantified by an analog-to-digital converter and stored and displayed as a digital image.

   PSP plates are made in sizes similar to intraoral films, and sizes commonly used for panoramic and cephalo-metric imaging.

   Before PSP is used the plates must be erased to eliminate 'ghost images' from prior exposures.

   Following exposure, plates should be processed as soon as possible, as the trapped electrons are spontaneously released over a period of time.

   The latent image can be read by:
   - Stationary plate scans
   - Rotating plate scans
5. *Flat Panel Detectors*: These provide a relatively large matrix areas with pixel sizes less than 100 microns. This allows direct digital imaging of larger areas of the body, including the head. These are of two types: Indirect detectors that are sensitive to visible light, and an intensifying screen is used to convert X-ray photons to light. Direct detectors which used a photoconductor material (selenium) with properties similar to silicon and a higher atomic number that permits more efficient absorption of X-rays.

C. Digital Image Display
   i. Cathode Ray Tube (CRT) which are used in conventional computer monitors.
   ii. Thin Film Transistor (TFT) is used in laptop and flat panel computer displays.

The computer digitizes, processes and stores information received from the sensor. The computer monitor allows

for immediate viewing of this exposure. The speed of image recording is extremely useful during certain dental procedures, such as placement of surgical implants or during root canal therapy instrumentation.

The image may be:

i. Stored permanently in the computer.
ii. Printed on a hard copy for patient record.
    a. Film printer.
    b. Paper printer.
iii. Transmitted electronically to insurance companies or referring dental specialists.

The computer offers various features for viewing the image:

i. Split screen technology: which allows the operator to view and compare multiple images on the same screen. This helps in the comparison and evaluation of disease progression and treatment results.
ii. Magnification, this allows better viewing and linear and angular measurements can also be obtained, e.g. for measuring root length.
iii. Image restoration: defects in the raw data received are corrected before the image becomes visible on screen.
iv. Image enhancement: most image enhancement operations are applied to make the image visually more appealing. This is done by adjusting the:
    a. Brightness and contrast; this can be achieved by changing the display of the image without changing the image.
    b. Sharpening and smoothening.
    c. Color
    d. Digital Subtraction Radiography (DSR): enhances visualization of the mineral changes that have occurred over time against a homgenous background of unchanged anatomy.
v. Image analysis: these operations are designed to extract non-pictorial information from image that is diagnostically relevant.
    a. Segmentation: the aim is to simplify the image and reduce it to its basic components. Image is separated foreground from background.
vi. Image Compression: here the image is compressed by reducing the number of digital image files for storage or transmission. Lossless (reversible) or lossy (irreversible)
vii. Image Synthesis: synthesizing new images based upon image data acquired from multiple projections. The purpose of these modalities is to access information about the object of interest in three dimensions. CT, MRI and Positron Emission Tomography Scanners are amongst the most well known and sophisticated image synthesizers for maxillofacial imaging.
    a. Tomosynthesis: this is based on selective focusing of an arbitrary slice through the object by shifting and adding a set of basic projections. This has limited applications in dentistry.
    b. Localized computed tomography: (micro-CT radiography, microtomography) is based on the same principles as CT. This is useful *in vitro* for study of mineral tissues. CT can be used to identify and delineate pathological processes and their extent, display trauma, assess paranasal sinuses, evaluate the bony component of TMJ and sites for pre-surgical implant planning, as to see and dicipher complex facial fractures.

Advantages

1. Superior gray scale resolution
2. Easy reproducibility
3. Reduced exposure to radiation
4. Increased speed of image viewing
5. Lower equipment and film cost.
6. Increased efficiency.
7. Enhancement of diagnostic image.
8. Excellent quality image with no loss of quality commonly associated with conventional chemical processing.
9. Image processing, enlargement and reconstruction for specific diagnostic purpose is possible.
10. With the aid of the computer, detection of defects and three dimensional visualization of dental structures based on radiographic data is possible.
11. Effective patient education tool.

Disadvantages

1. Initial set-up is costly.
2. Image quality is still a source of debate.
3. Sensor size–these are thicker than intraoral films and therefore not patient compliant.
4. Infection control, the sensor has to be covered adequately in a disposable plastic wrapper.
5. Legal issues, because the original digital image can be manipulated, it is debatable whether digital radiographs can be used as evidence in lawsuits.

Other Clinical Applications besides Radiographic Imaging:

1. *Microscopic Imaging*
   Medical grade single frame digital cameras are available which may be attached to dental microscopes, and

produce high quality VL images. These high-tech cameras provide single frame capture and motion digital video from the operating microscope directly to the computer via USB, fire-wire port or memory card.

2. *Intraoral Cameras*
   These are dental cameras that can photograph a single tooth, a group of teeth or a patient's full face. These are good for recording the condition of the soft and hard tissues for documentation and patient education.These cameras are available with barrier sheaths to ensure zero cross contaminations.
3. *Fiberoptic Imaging*
   Fiberoptic endoscopes specifically for use in the oral cavity, to view the root canals. This consists of a 0.7 mm and 11.8 mm diameter light fiberoptic probe, the former can be inserted into the root canal for internal viewing. The scope sends images to a solid state video camera, a medical grade video monitor and digital image capture device. Each probe consists of a flexible fiberoptic bundle with fibers that emit light generated by the metal halide light source and others that transmit the image. The digital processing unit filters the image to produce an enhanced, consistant image. Storage and retrival of images can be accomplished with connection to the clinical chair side work station. Disposable optical grade plastic sheaths are used over the distal end of the probe for infection control.
4. *Photostimulable Phosphor Radiography (PPR)*
   This system is more accurate for assessing trial file length for endodontic measurements over the film based measurements.
5. *Digital Photography*
   Inexpensive and records the images with a high degree of accuracy. These have a better resolution, accurate color values and no occurance of ghosting or distortion.

Digital Image processing Tools for Dental Applications.

a. Image Enhancement
   - Contrast Enhancement
   - Filtering
   - Subtraction
   - Color.

b. Image Restoration
   - System defects
   - Geometric transformation.

c. Image Analysis
   - Measurement
   - Segmentation
   - Feature extraction
   - Object classification.

d. Image Compression
   - Lossless
   - Lossy.

e. Image Synthesis.
   - Tomosynthesis
   - TACT
   - Localized CT.

Digital Subtraction Radiography (Fig. 15.2)

The diagnostic problem in a radiographic examination lies primarily in the identification of image features, caused by a pathological process, buried in a back ground of normal anatomical structures. During interpretation, the desired part has to be separated from the irrelevant distribution of other structures. The "other structures" which do not contain diagnostic information of interest have been termed as 'noise.'

Technique

The reference radiograph is digitized and converted into its positive image by the computer. The subsequent radiograph is then displayed on the same server and aligned to the reference image and then digitized.

Subtraction of the gray levels between the two images is then performed. Any change that has occurred between the original radiograph and the subsequent radiograph shows up as light or dark areas. Loss of bone is seen as dark areas and gain of bone as light areas.

Applications

- Diagnosis of stuble changes in bone, e.g. it can be used to assess bone levels before and after periodontal therapy.
- Study of the periapical region.
- Study of the superior surface of the condyle.

Digital Image Processing of Dentomaxillofacial Radiographs

This is a method by which film images are converted into a digital format and then enhanced, so that a better image quality is achieved.

It is made up of two parts:

i. The drum scan with reading and writing units.
ii. Mini computer with its subsystems.

Fig. 15.2: Application of digital subtraction radiography for detection and quantification of periodontal bone healing. **A.** Base line image. **B.** Standardized 1-year follow-up image. **C.** Subtraction image showing increase in bone (arrow)

Advantages

- The over all contrast is improved and the structures are more clearly visualized in the processed image.
- The trabecular fine marrow spaces are excellently visualized.
- Low density as well as high density structures are equally enhanced and better visualized.

Disadvantage

- Artifacts and noise may be evident on the processed images, especially in the case of periapical radiographs.

BIBLIOGRAPHY

1. Allan G Farman. Guest Editorial, Dimensions in Computed Maxillofacial Imaging, J. of Indian Academy of Oral Medicine and Radiology, 2004;16(2):91-95.
2. Langland OE, Langlais RP. Special Radiographic Techniques. In Principles of Dental Imaging. Baltimore, Williams and Wilkins, 1997; 265-87.
3. Levato C. Are you ready for digital radiography? Dental Practise and Finance 1999;7:17-24.
4. Lusk LT. Comparison of film based and digital radiography. J Practical Hygiene 1998;7:45-50.
5. Miles DA, Van Dis ML, Jenson CW, Ferretti A. Digital Imaging. In Radiographic Imaging for Dental Auxillaries, 3rd ed. Philadelphia, WB Saunders, 1999; 149-63.

Section Six
Radiographic Interpretation

16

Radiographic Prescription, Quality Control and Infection Control

The Importance of Prescribing a Dental Radiograph

The dentist should be well aware of the importance of dental radiographs and why they are necessary for comprehensive patient care.

Dental radiographs are essential for (Table 16.1)

1. Diagnostic purposes to enable the dental professional to identify conditions which would otherwise go undetected.
2. The primary use is to help in the detection of diseases, lesions and conditions of the teeth and bones.
3. The benefit of the disease recognition far out weighs the risk of small doses of radiation.
4. Many disease which have no clinical signs or symptoms, may be detected on the radiograph.

The dentist must have sufficient knowledge and technical skill to take a radiograph.

The responsibility of the dental professional includes:

1. Positioning, exposure and processing of the dental X-ray films.
2. Mounting and identification of radiographs.
3. Educating the patients about dental radiographs.

Table 16.1: Common dental radiographic examinations and their properties

Type of examination	*Coverage*	*Resolution*	*Relative exposure**	*Detectable disease*
Intraoral radiographs				
Periapical	Limited	High	1	Caries, periodontal disease, occult disease
Bitewings	Limited	High	10	Caries, periodontal bone level
Full mouth periapical	Limited	High	14-17	Caries, periodontal disease, dental anomalies, occult disease
Occlusal	Moderate	High	2.5	Dental anomalies, occult disease, salivary stones, expansion of jaw
Extraoral radiographs				
Panoramic	Broad	Moderate	1-2	Dental anomalies, occult disease, extensive caries periodontal disease, periapical disease, TMJ
Conventional tomography/slice	Moderate	Moderate	0.2-0.6	TMJ, implant site assessment
CT/head	Broad	High	25-800	Extent of craniofacial pathology, fracture implants
MRI	Broad	Moderate	–	Soft tissue disease, TMJ
Skull	Broad	Moderate	30	Fracture, anatomic relation, jaw pathology

*The parameters assume use of F-speed film and rectangular collimation for periapical films, round collimation for bitewings and occlusal views and rare-earth screens for panoramic examinations. With D-speed film the intraoral values are more than doubled compared with F-speed film, and with round collimation the perapical values increase by 2.5 times compared with rectangular collimation. Frederiksen N, Benson B, Sokolowski T: Effective dose and risk assessment from computed tomography of the maxillofacial complex, Dentomaxillofac Radiol 24:55, 1995; Scaf G et al: Dosimetry and cost of imaging osseointegrated implants with film-based and computed tomography, Oral Surg Oral Med Oral Pathol Oral Radiol and Endod 83:41, 1997: White SC: 1992 assessment of radiation risks from dental radiology, dentomaxillofac radiol 21:118, 1992.

4. Maintaince of darkroom facilities and processing equipment.
5. Implementation and monitoring of quality control procedures.
6. Ordering of dental X-ray equipment and supplies.

The Dental practitioner must also have defined professional goals, like:

1. Patient protection.
2. Operator protection.
3. Patient education.
4. Operator competence.
5. Operator efficiency.
6. Production of high quality radiographs.

A quality assurance plan ensures the production of high quality radiographs and includes both quality control tests and quality administration procedures.

Quality control tests are tests that are used to monitor dental X-ray equipment, supplies, and film processing. The following quality control tests are recommended:

1. *X-ray machines*: Dental X-ray machines should be tested for minor malfunctions, output variations, collimation problems, tube head drift, timing errors, and inaccurate kilovoltage and milliamperage readings. These should be performed on a yearly basis (Table 16.2, Figs 16.1 and 16.2).
2. *X-ray films*: The fresh film test should be done to determine whether the dental film is fresh and has been properly stored and protected. This test should be done each time a new box of films is opened (Table 16.3).
3. *Screens and cassettes*: Cassettes should be examined periodically for adequate closure, light leaks and warping.

Fig. 16.1: Device for measuring exposure of an X-ray machine. The aiming cylinder of the X-ray machine is positioned on the center of the top and an exposure made. The display on the front gives the output in Roentgens

Table 16.2: Quality control tests for dental X-ray machines

- X-ray output
- Focal spot size test
- Collimation-beam alignment test
- Half value layer (HVL) test
- Timer test
- Milliamperage test
- Kilovoltage test

The film screen contact test must be used to determine the adequacy of screen film contact, on a regular basis.

4. *Darkroom lighting*: The light leak test should be done to evaluate the darkroom for leaks and the safelighting test to test the proper use of safelights. These tests should be done every six months (Fig. 16.3).
5. *Processing equipment*: Manual and automatic processing equipment must be carefully maintained and monitored daily. In the manual processing, the thermometer and timer must be accurate, the temperatures of the water bath, developer and fixer solutions should be regularly monitored. In the automatic processing, test films should be used to check the functioning of the processor. These tests should be done on a daily basis.
6. *Processing solutions*: The developer strength can be monitored by a reference radiograph, step wedge radiographs or a normalizing device. The fixer solution can be checked by performing a clearing test. These tests should also be performed on a daily basis. (Table 16.4)

The Quality administration procedures include a description of the Quality Assurance Plan, the assigment of duties, a monitoring schedule, record keeping logs, a plan for evaluation and revision, and in service training. The dentist is finally responsible for the overall quality assurance plan,

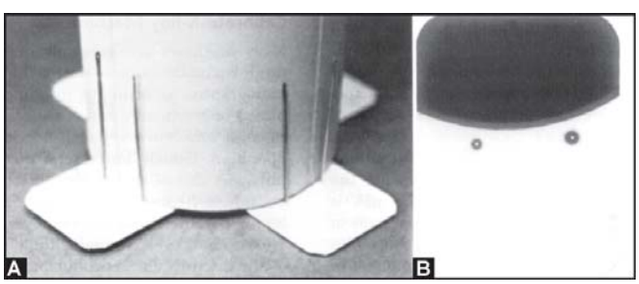


Fig. 16.2: A. The alignment of the collimator of the X-ray beam and the end of the aiming cylinder can be checked by making a cross pattern of the film, centering the aiming cylinder, marking the periphery with needles and making an exposure. **B.** One of the processed radiographs showing the dark exposed area just inside the holes. If this pattern is seen on all films, then good alignment is demonstrated

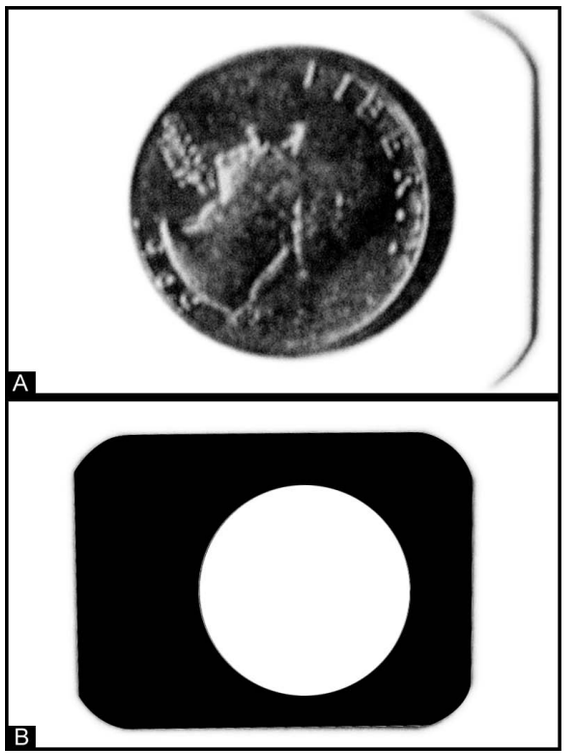


Fig. 16.3: A. Coin test for safe lighting. Coin placed on unexposed film under the safe light. **B.** Developed film showing outline of coin, indicating that the safelight intensity is too great and not safe. (From Frommer HH: Radiology for Dental Auxiliaries, 5th ed. St. Louis, Mosby-year, book 1992.)

Table 16.3: Fresh film test

Take an unexposed film from a newly opened box and process the unexposed film using newly prepared processing solutions.
The film is then viewed.
Fresh film: The processed film appears clear with a slight blue tint, it means that the film has been properly stored and protected.
Fogged film: The processed film appears fogged, it means that the film has expired and/or it has been improperly stored and /or exposed to radiation.

and the diagnostic quality of all radiographs, regardless of who exposes and processes the film (Fig. 16.4).

Infection control: To protect ourselves and the patient, dental professionals must understand and use infection control protocols. The primary purpose of infection control procedures is to prevent the transmission of infectious diseases.

Disease transmission involves pathogens or micro-organisms that are capable of causing disease. In dentistry, disease transmission may occur due to any of the following:

1. Direct contact with pathogens in saliva, blood, respiratory secretions or lesions.
2. Indirect contact with contaminated objects or instruments.
3. Direct contact with airborne contaminants present in spatter or aerosols or oral and respiratory fluids.

Table 16.4: Quality control tests for film processing

Day	*Solution strength*	*Quality control tests*	*Test results*
1	Use fresh, full- strength processing solutions.	Reference radiograph: Using correct exposure factors, expose and process one film. This film becomes the reference radiograph.	Reference radiograph: This demonstrates optimum film contrast and density.
		Stepwedge radiograph : Expose 20 stepwedge films, process one film on day 1. This film becomes the standard radiograph.	Stepwedge radiograph : This demonstrates optimum film contrast and density.
2,3, etc.	Fresh processing solutions weaken with time and use; exhausted solutions result.	Reference radiograph : each day, expose and process one film to compare with the reference radiograph.	Compare films: Compare the daily film to the reference radiograph; If densities match, continue processing. If densities do not match, replace processing solutions.
		Stepwedge radiograph: Each day, process one of the previously exposed stepwedge films.	Compare films: Compare the daily film to the standard radiograph; If densities match, continue processing. If densities differ by more than two steps on the stepwedge, replace processing solutions.

Radiation dosimetry report

Account No.	Series code	Analytical work order	Report date	Dosimeter recieved	Report time in work days	Page No.
103702	RAD	992150087	13/11/05	6/9/05	4	1

Participant number	Name / ID number / Birth date / Sex	Dosimeter	USE	Radiation quality	Dose equivalent (mrem) for periods shown below			Year to date dose equivalent (mrem)			Lifetime dose equivalent (mrem)			Records for year	Inception date MM/YY
					DEEP DDE	EYE LDE	SHALLOW SDE	DEEP DDE	EYE LDE	SHALLOW SDE	DEEP DDE	EYE LDE	SHALLOW SDE		
For monitoring period						05/01/03	05/31/03		2003						
00004	Control Control Control	J P U	CNTRL CNTRL CNTRL		M M	M M	M M							5	07/97 07/97 07/97
00189	S. Sawant 336211118 29/12/1978 F	P	WHBODY		M	M	M	9	10	12	29	31	42	5	07/98
00191	D. Sawant 478921214 14/10/1970 M	P J	WHBODY	PN P NF	90 60 30	90 60 30	90 60 30	100 70 30	100 70 30	100 70 30	200 170 30	200 170 30	200 170 30	5	07/98
00202	S. Doke 982744411 7/10/1964 F	P U	WHBODY RFINGR		M	M	M M	M	M	M 30	M	M	M 30	5	02/97 02/97
	V. Balerao	P P U	COLLAR WAIST	PL P	119 10 19	119 11 119	113 11 113	33	185	174	1387	2308	2320	5	08/99 08/99
00005	895500011 8/5/1971 M		ASSIGN NOTE R FINGER		Assigned dose based on EDE1 calculation		140			690			2180		08/97
00203	V. Kokade 335433511 25/8/1951 M	P U	WH BODY RFINGR		Absent Absent			M	M	M M	M	M	M M	4	07/99 07/99
00204	M. Mahajan 416681541 21/03/1970 F	P	WH BODY		3	3	3	12	11	11	22	21	21	5	11/96
00198	H. Gaonkar 355381496 15/5/1972 M	P	WH BODY NOTE		40 Calcu- lated	40	40	200	200	200	240	240	240	5	07/97
M. Minimal reporting service of IMREM electronic media to follow this report						Quality control release : LMR					1-PR	6774-	PT1	31-N1	-21587

Fig. 16.4: Sample radiation dosimetry report showing that H. Gaonkar received an exposure of 0.60 mSv (60 mrem) during the month-reported. The report also shows totals for the calender quarter, year to date, and permanent or lifetime exposure

For infection to occur via one of the described routes of transmission, three conditions must be present:

1. A susceptible host.
2. A pathogen with sufficient infectivity and numbers to cause infection.
3. A portal of entry through which the pathogen may enter the host.

The Center for Disease Control and Prevention has published infection control guidelines entitled, "Recommended Infection Control Practices for Dentistry". This document specifies and outlines specific infection control measurements that pertain to dentistry.

These recommended infection control practices are applicable to all settings in which dental treatment is provided. The same infection control procedures must be used for each patient. There are no exceptions, and no extra precautions should be used on any select patients (Table 16.5).

Specific infection control procedures are recommended before exposure, during exposure, following exposure and during processing (Tables 16.6 and 16.7).

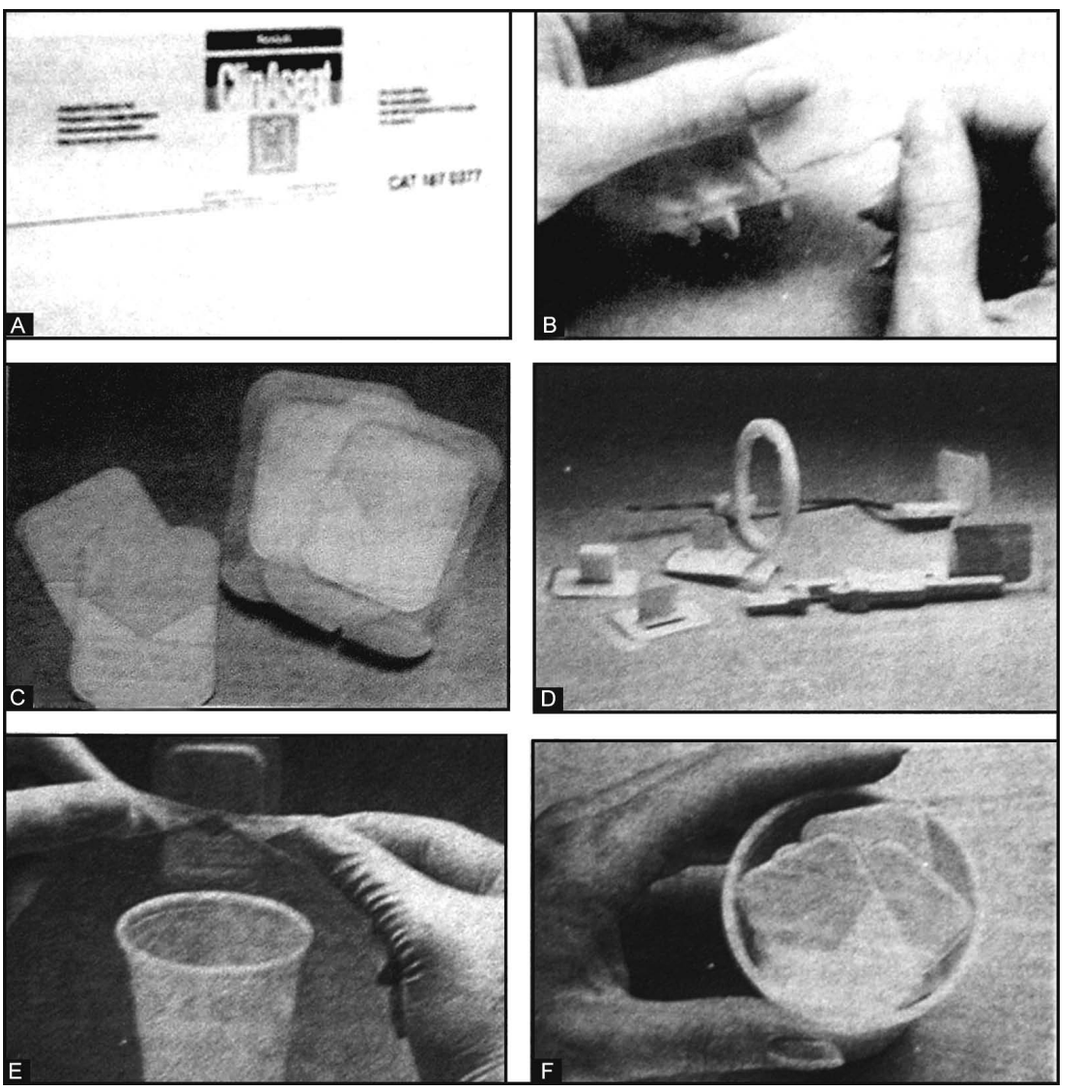


Fig. 16.5: A. Commercial barrier envelopes for dental film. Packaging of Kodak barrier envelope. **B.** Insertion of the film into envelope. **C.** Protected and unprotected film. **D.** Bite-wing and periapical applications of protected films. **E.** Film packet removal from envelope without contamination. **F.** Uncontaminated film ready for processing. Courtesy of Eastman Kodak Company, Rochester, NY)

Table 16.5: Recommended infection control practises for dentists

- Vaccination of dental professionals.
- Use of protective attire and barrier techniques.
- Handwashing and care of hands.
- Proper use and care of sharp instruments and needles.
- Sterilization or disinfection of instruments.
- Cleaning and disinfection of dental unit and environmental surfaces.
- Disinfection of the dental laboratory.
- Use and care of handpiece, antiretraction valves and other intra oral dental devices attached to air and water lines of dental units.
- Single use of disposable instruments.
- Proper handling of biopsy specimens.
- Proper use of extracted teeth in dental educational settings.
- Proper disposal of waste materials.
- Implementation of recommendations.

Table 16.6: Check list for infection control in dental radiography

Before exposure	*During exposure*	*Following exposure*
Treatment Area: The following must be covered or disinfected, * x-ray machine * dental chair * work area * lead apron	Film handling: Must include the following, * after exposure, dry film with paper towel. * place dried film in disposable container.	Prior to Glove removal: * dispose off all contaminated items. * place film holding devices in areas designated for contaminated.
Supplies and equipments: The following must be prepared prior to seating the patient, * film * film-holding device * cotton rolls * paper towel * disposable container	Film holding devices: These must be handled as follows, * transfer film-holding device from work area to mouth and back to work area. * never place film-holding devices on uncovered countertop.	After glove removal: * wash hands. * remove lead apron.
Patient preparation: The following must be performed prior to wearing gloves, * adjust chair * adjust head rest * place lead apron * remove objects		
Radiographer preparation: The following must be completed prior to exposure, * wash hands * put on gloves * prepare film holding devices		

Table 16.7: Check list for film handling during processing (Figs 16.5 and 16.6)

With barrier envelopes	*Without barrier envelopes*
Place disposable towel on the work surface in darkroom.	Place disposable towel on the work surface in darkroom.
Place container with contaminated films next to the towel.	Place container with contaminated films next to the towel.
Put on gloves.	Put on gloves.
Take one contaminated film out of the container.	Turn out dark room lights and secure the door.
Tear open barrier envelope.	Take one contaminated film out of the container.
Allow film to drop on paper towel.	Open film tab and slide out lead foil backing and black paper.
Do not touch film with gloved hands.	Rotate foil away from black paper and discard.
Dispose off barrier envelope.	Without touching the film, open the black paper wraping.
After all barrier envelopes have been opened, dispose off container.	Allow film to drop on paper towel.
Remove gloves and wash hands.	Do not touch film with gloved hands.
Turn off dark room lights and secure door.	Discard black paper wrapping.
Unwrap and process films.	Remove gloves and wash hands.
Label a film mount, paper cup, or envelope with the patient's name and use it to collect the processed films.	Process films. Label a film mount, paper cup, or envelope with the patient's name and use it to collect the processed films.

Legal Issues

The dentist is responsible for:

1. Prescribing and interpreting dental radiographs.
2. Exposure and processing of the said radiographs.
3. Disclosing requisite information and obtaining informed consent from the patient before exposing radiographs.
4. The dental record must include documentation of informed consent and the exposure of radiographs, that is the number and type of films, the rationale of exposure, and the interpretation.
5. Legally the dental radiograph is the property of the dentist. The patient, however, does have reasonable access to the dental radiographs.

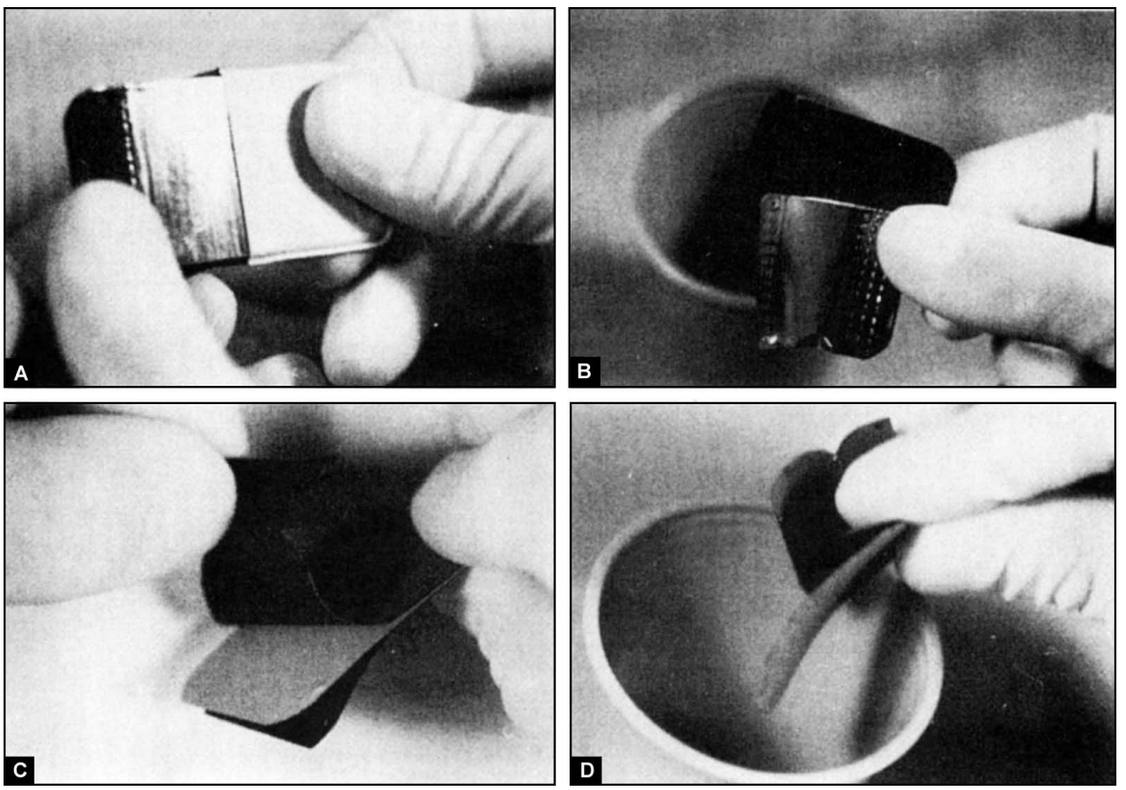


Fig. 16.6: A. Method for removing films from packet without touching them with contaminated gloves. Open tab and slide lead foil and black inter leaf paper from wrapping. Illustration of steps used to open a size 2 film packet without contaminating the film. **B.** Rotate foil away from black paper and discard. **C.** Open paper wrapping. **D.** Allow film to fall into a clean cup. (From Goaz PW, White SC. Oral Radiology: Principles and Interpretation, 3rd ed. St. Louis Mosby-Year Book, 1994)

6. In most cases the dentist cannot treat a patient who refuses dental radiographs; refusal compromises diagnosis and treatment. No document can be signed that releases the dentist from liability.

BIBLIOGRAPHY

1. Eastman Kodak Co. Infection Control in Dental Radiography. In Infection control in Dental Office, Rochester, Eastman Kodak Co, 1989;1-11.
2. Frommer HH. Infection Control in Radiology for Dental Auxillaries, 6th ed. St. Louis, Mosby Year Book, 1996; 89-99.
3. Goaz PW, White SC. Radiographic Infection Control. In: Oral Radiology, Principles and Interpretation, 3rd. ed, St. Louis, CV Mosby, 1994.
4. Mason, Hing LR. Infection Control, In: Fundamentals of Dental Radiography, 3rd. ed. Philadelphia, Lea and Febiger, 1990; 230-42.

17

Normal Anatomy on Intraoral and Extraoral Radiographs

The radiographic recognition of disease requires some knowledge of the radiographic appearance of normal structures. A good diagnosis mandates appreciation of a wide range of variation in the appearance of normal structures. Similarly most patients demonstrate many of the normal radiographic landmarks, but it is a rare patient who shows them all. Hence the absence of one or several landmarks in any individual should not be necessarily considered abnormal.

The radiographic appearance of various structures which can be visualized on the intraoral periapical radiograph can be classified as under:

1. Teeth
2. Supporting structures
3. Maxilla
4. Mandible.
5. Others, restorative materials.

All these structures appear either radiopaque or radiolucent.

However, there are many structures which may not be visible on the intraoral periapical radiographs, these may be studied and observed on:

1. Panoramic radiographs
2. Cephalometric radiographs
3. Skull projections.

Normal anatomical landmarks seen on the intraoral periapical radiographs may also be classified as:

1. Radiopaque
2. Radiolucent.

Radiopaque

A. Maxilla	B. Mandible
1. Enamel	1. Enamel
2. Dentin	2. Dentin
3. Cementum	3. Cementum
4. Lamina dura	4. Lamina dura
5. Alveolar crest	5. Alveolar crest
6. Cancellous bone	6. Cancellous bone
7. Nasal septum	7. Genial tubercles
8. Anterior nasal spine	8. Mental ridge
9. Floor of the nasal cavity	9. Mylohyoid ridge
10. Inferior nasal conchae	10. External oblique ridge
11. Nasolabial fold	11. Inferior border of the mandible
12. Floor of the maxillary sinus	12. Coronoid process
13. Septa in maxillary sinus	13. Internal oblique ridge
14. Inverted Y- in maxillary sinus	
15. Zygomatic process of the maxilla	
16. Zygoma (malar bone)	
17. Pterygoid plates	
18. Hamular process	
19. Maxillary tuberosity	

Radiolucent

A. Maxilla	B. Mandible
1. Pulp	1. Pulp
2. Periodontal ligament space	2. Periodontal ligament space

3. Nutrient canals	3. Nutrient canals
4. Intermaxillary suture	4. Lingual foramen
5. Nasal fossa (nasal cavity)	5. Symphysis
6. Incisive foramen	6. Mental fossa
7. Superior foramina of nasopalatine canal	7. Mental foramen
8. Incisive fossa (lateral or canine fossa)	8. Mandibular canal
9. Nasolacrimal canal	9. Submandibular fossa
10. Maxillary sinus	
11. Nose	
12. Nasolabial fold	

Tooth

The tooth structure that can be viewed on the radiograph are: (Fig. 17.1).

1. *Enamel*: This is the densest structure found in the human body. It is seen as the outer most radiopaque layer of the crown of a tooth on the radiograph.
2. *Dentin:* is found beneath the enamel layer of a tooth and surrounds the pulp cavity. It appears radiopaque and comprises most of the tooth structure. Dentin is less radiopaque than enamel.
3. *Cementum:* is not usually apparent on the radiograph because the cemental layer is very thin and the contrast between the cementum and dentin is very low.

   Diffuse radiolucent areas with ill-defined borders may be apparent radiographically on the mesial and distal aspects of the teeth in the cervical region between the edge of the enamel cap and the the crest of the alveolar ridge, (cementoenamel junction), this is called cervical burn out, which may be mistaken for cervical or root caries.
4. *Pulp cavity*: This consists of the pulp chamber and the root canals. It contains the blood vessels, nerves and lymphatics and appears relatively radiolucent on the radiograph.

   The size of the pulp chamber is generally large in children than in adults because it decreases with age owing to the formation of secondary dentin. Great variation exists between individuals in size of the pulp chambers and extent of the pulp horn.

   The root canal may be apparent, (Figs 17.2A and B)
   - Extending to the apex of the root.
   - In some teeth the canal may appear constricted in the region of the apex and thus not discernible in the last few millimeter or so of its length.
   - In the above mentioned cases the canal may exit on the same side of the tooth, just short of the radiographic apex.
   - At the end of the developing tooth root, pulp canal diverges and the walls of the root rapidly taper to a knife edge. In the recess formed in the root walls and extending a short distance beyond is a small rounded, radiolucent area in the trabecular bone, surrounded by a thin layer of hyperostotic bone. This is the dental papilla surrounded by its bony crypt. The papilla forms the dentin and primordium of the pulp (Fig. 17.2C).

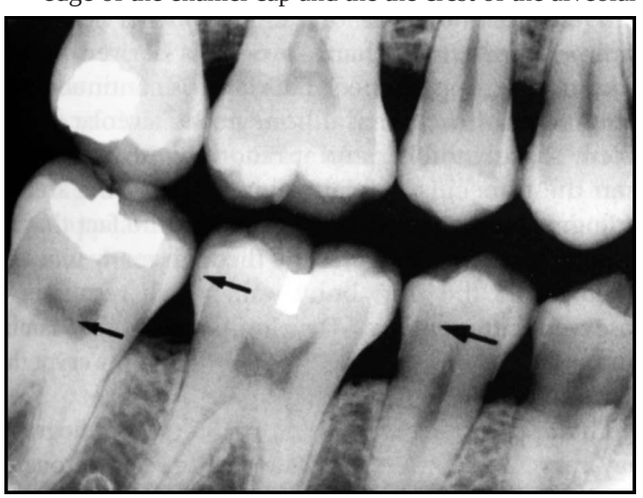


Fig. 17.1: Teeth are composed of pulp (arrow on the second molar) enamel (arrow on first molar), dentin (arrow on second premolar), and cementum usually not visible radiographically

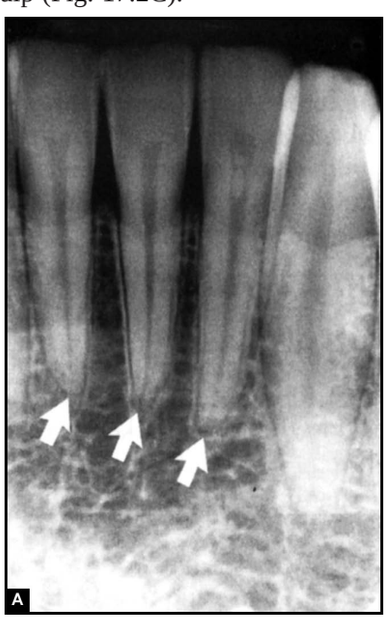


Fig. 17.2A: Root canal; adult incisor teeth arrows at the root apex

Fig. 17.2B: Although the root canal is not radiographically visible in the apical 2 mm of the tooth, anatomically it is present (arrow)

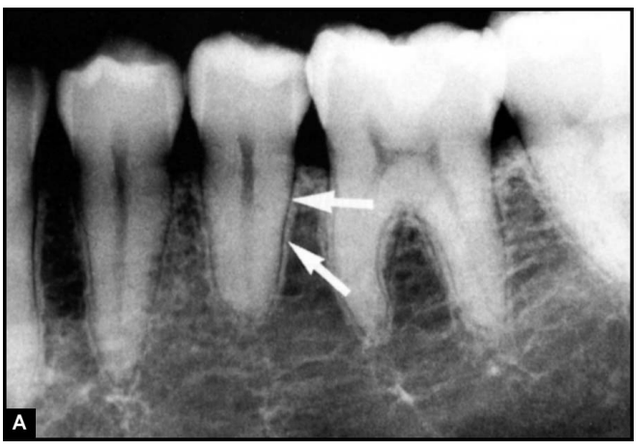


Fig. 17.3A: Lamina dura appears as a thin opaque layer of bone around teeth

In mature teeth the shape of the pulp chamber may change. With aging occurs a gradual deposition of dentin. This process begins apically, precedes coronally, and may lead to pulp obliteration. Trauma may also stimulate dentin production leading to reduction of the size of the pulp chambers and canals.

Supporting Structures

1. *Lamina Dura* (Figs17.3A to C):
   This is the wall of the tooth socket that surrounds the tooth, it is made up of dense cortical bone.
   On the radiograph lamina dura appears as
   - A thin dense radiopaque line that surrounds the root of the tooth. It is continuous with the shadow of the cortical bone at the alveolar crest.
   - It is slightly thicker than the trabeculae of the cancellous bone in the area.
   - When the X-ray beam is directed through the relatively long expanse of the structure, the lamina dura appears radiopaque and well-defined.
   - When the beam is directed more obliquely, the lamina dura appears more diffuse and may not be discernible.
   - The thickness and density of the lamina dura will vary with the amount of occlusal stresses. It is wider and more dense around roots of teeth in heavy occlusion, and thinner and less dense around teeth not subjected to occlusion function.
   - Double lamina dura image appears if the mesial or distal surfaces of the root present two elevations in the path of the X-ray beam.

Fig. 17.2C: A developing root shown by a divergent apex around the dental papilla (arrow) which is enclosed by a bony crypt

Fig. 17.3B: Lamina dura around recent extraction sockets

Fig. 17.3C: Lamina dura is poorly visualized on the distal surface of the premolar (arrows), but is clearly seen on the mesial surface

- Presence of an intact lamina dura around the tooth indicate a vital pulp, however in some cases its absence may be normal.

2. *Alveolar crest* (Fig. 17.4):
   This is the most coronal portion of the alveolar bone found between the teeth. It is made up of dense cortical bone and is continuous with the lamina dura.
   On the radiograph the alveolar crest appears as
   - A radiopaque and is typically-located 1.5 to 2 mm. below the junction of the crown and the root surfaces (cementoenamel junction).
   - Anteriorly the crest is reduced to a point of bone and appears as a dense radiopaque line, whereas posteriorly, it is flat, parallel with or slightly below a line connecting the cemento enamel junction of adjacent teeth.
   - The crest of the bone is continuous with the lamina dura and forms a sharp angle with it. Rounding of these sharp angles is indicative of periodontal disease.
   - The alveolar crest may recede apically with age and show marked resorption with periodontal disease.
3. *Periodontal Ligament Space* (Figs 17.5A to C):
   It is the space between the root of the tooth and the lamina dura. The PDL space contains connective tissue fibers, blood vessels and lymphatics.
   On the radiograph the PDL appears as
   - A thin radiolucent line around the root of the tooth, it is usually of uniform thickness.
   - It may be thinner in the middle of the root and slightly wider near the alveolar crest and the root apex, suggesting that the fulcrum of the physiologic movement is in the region where the PDL is thinnest.
   - The thickness of the PDL is less around the root of the embedded teeth and those that have lost their antagonists.
   - The appearance of double PDL space is created by the shape of the tooth. When the X-ray beam is directed so that two convexities of a root surface appear on the film, double PDL space may be seen.
4. *Cancellous Bone* (Figs 17.6A to C):
   This is soft spongy bone located between two layers of dense cortical bone. It is composed of numerous bony

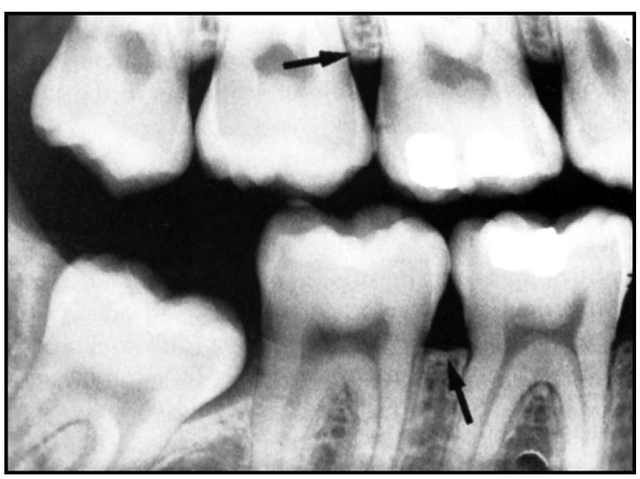


Fig. 17.4: The alveolar crests (arrows) are seen as corticated borders of the alveolar bone between the teeth

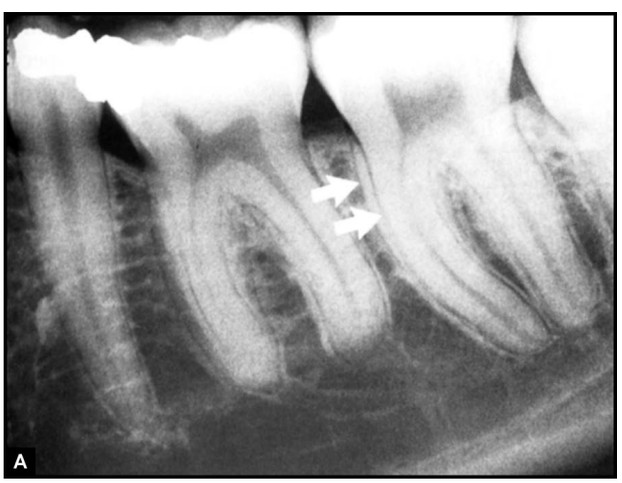


Fig. 17.5A: A double periodontal ligament space and lamina dura (arrow) seen where there is a convexity of the proximal surface of the root

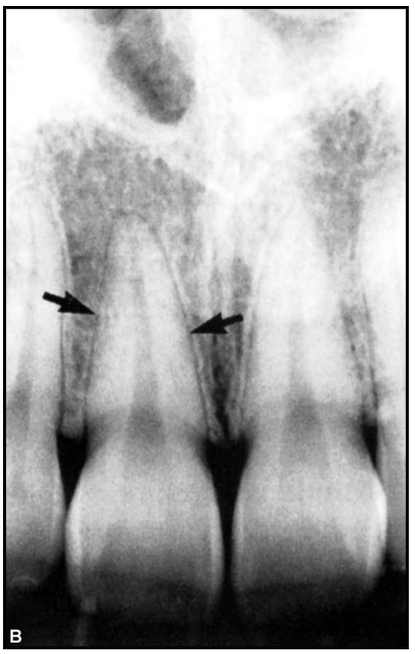


Fig. 17.5B: The periodontal ligament space (arrows) is seen as a narrow radiolucency between tooth root and lamina dura

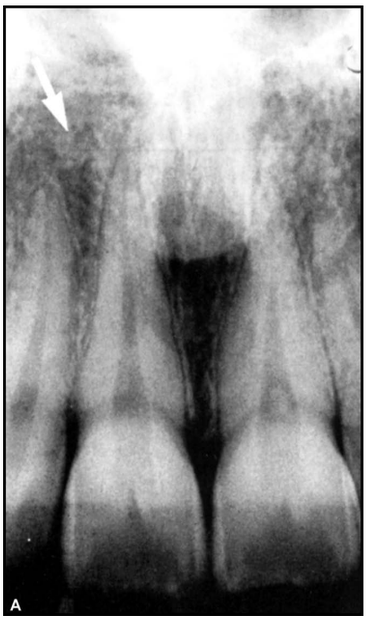


Fig. 17.6A: The trabecular pattern in the anterior maxilla is characterized by fine trabecular plates and multiple small trabecular spaces (arrow)

trabeculae that form a lattice like network of intercommunicating spaces filled with bone marrow.

On the radiograph the cancellous bone appears as

- Predominantly radiolucent with the trabeculae appearing radiopaque in a criss cross pattern.

17.5C: The periodontal ligament space appears wide on the mesial surface of the canine (arrows) and thin on the distal surface

Fig. 17.6B: The trabecular pattern in the anterior mandible is characterized by coarser trabecular plates and larger marrow spaces (arrow) than in the anterior maxilla

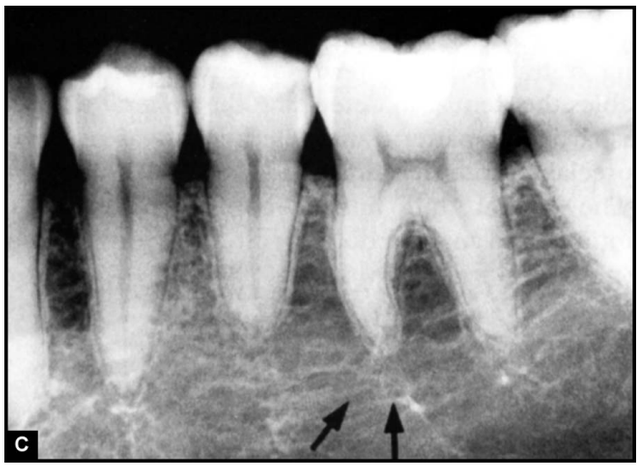


Fig. 17.6C: The trabecular pattern in the posterior mandible is quite variable, generally showing large marrow spaces and sparse trabeculation (arrows)

- *In the Maxilla*:
  - Anteriorly the trabeculae are thin and numerous forming a fine, granular, dense pattern and the marrow spaces are small and relatively numerous.
  - Posteriorly the pattern is similar but the marrow spaces are larger.
- *In the Mandible*:
  - Anteriorly the trabeculae are thicker, coarser and fewer than that in the maxilla with larger marrow spaces and are oriented more horizontally.
  - Posteriorly, the periradicular trabeculae and marrow spaces are larger than that in the anterior region.
- Ocassionally the trabecular spaces in the region may be so irregular and large that they may mimic pathological lesions.
- Sparse trabecular pattern that is over exposed may get "burnt out", suggesting the presence of disease.

Maxilla

The upper jaw is composed of two paired bones, the maxillae which meet at the center, to form the maxilla which is described as the cornerstone of the face. The maxilla forms the floor of the orbit of the eyes, the sides and floor of the nasal cavities and the hard palate. The lower border of the maxilla supports the upper teeth.

1. *Incisive Foramen (Nasopalatine or Anterior Palatine Foramen)* (Figs 17.7A and B):
   It is an opening located in the midline of the anterior portion of the hard palate, directly posterior to the central incisors. The nasopalatine nerve exists the maxilla through this foramen.
   On the radiograph it appears as
   - A small ovoid or round radiolucent area located between the roots of the maxillary central incisors.
2. *Superior Foramina of the Incisive Canal (Nasopalatine Canal)* (Figs 17.8A and B):
   These are two tiny openings or holes in bone that are located on the floor of the nasal cavity (foramina is the plural of foramen). The superior foramina are the openings of two small canals. These two small canals

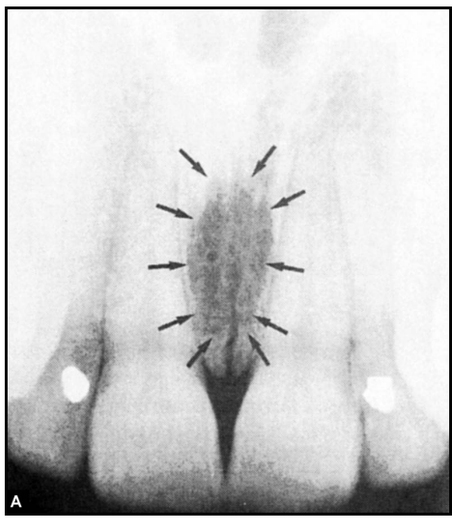


Fig. 17.7A: The incisive foramen appears as an ovoid radiolucency between the roots of the central incisors

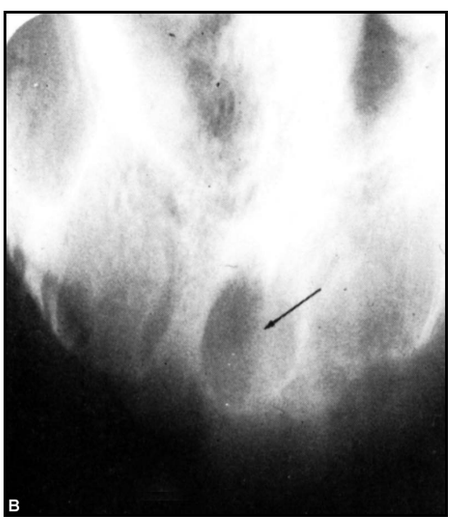


Fig. 17.7B: The arrow is pointing to the incisive foramina (naso palatine foramina) and may be incorrectly identified as a cyst

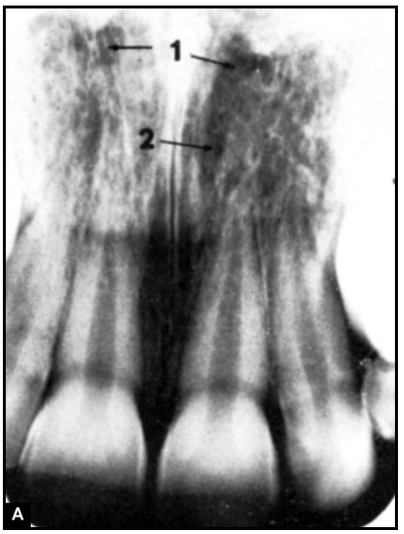


Fig. 17.8A: 1. Superior foramina of the incisive canal, 2. Incisive canal

extend downward and medially from the floor of the nasal cavity, and join together to form the incisive canal and share a common exit, the incisive foramen. The nasopalatine nerve enters the maxilla through the superior foramina, travels down the incisive canal and exits through the incisive foramen.

On the radiograph the superior foramina appear as

- Two small radiolucencies located superior to the apices of the maxillary central incisors, in the floor of the nasal cavity, near it's anterior border on both sides of the septum.

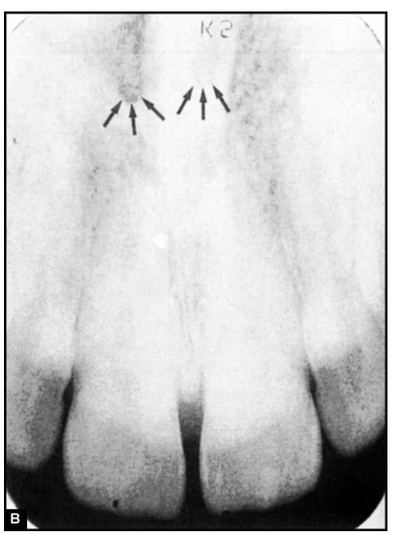


Fig. 17.8B: The superior foramen of the incisive canal appear as two small round radiolucencies

3. *Median palatine suture (Intermaxillary Suture)* (Figs 17.9, 17.17):
   It is the immovable joint between the two palatine processes of the maxilla. It extends from the alveolar bone between the maxillary incisors to the posterior hard palate.
   On the radiograph it appears as
   - A thin radiolucent line between the maxillary central incisors. This is bounded on both sides by dense cortical bone that appears radiopaque.
   - The suture may terminate at the alveolar crest in a small rounded or V-shaped enlargement.
   - As this suture fuses with age, it may appear less distinct radiographically.
4. *Lateral Fossa (Incisive Fossa, Canine Fossa)* (Fig. 17.10):
   It is a smooth depressed area of the maxilla located just inferior and medial to the infraorbital foramen between the lateral incisors and canine.
   On the radiograph it appears as:
   - A radiolucent area between the canine and the lateral incisors.
5. *Nasal Cavity (Nasal Fossa)* (Figs 17.11A and B):
   It is a pearshaped, air filled compartment of bone located superior to the maxilla. The inferior portion, or floor of the nasal cavity is formed by the palatal process of the maxilla and the horizontal portions of the palatine bones.

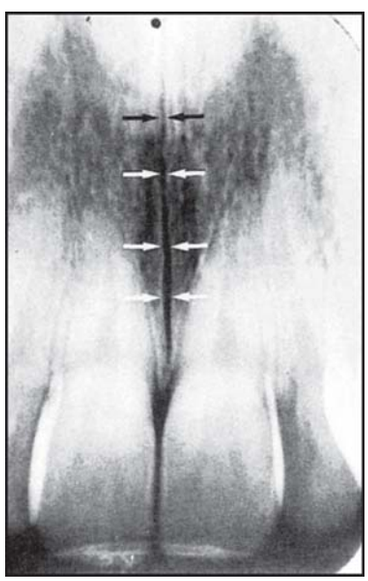


Fig. 17.9: The median palatine suture appears as a thin radiolucent line

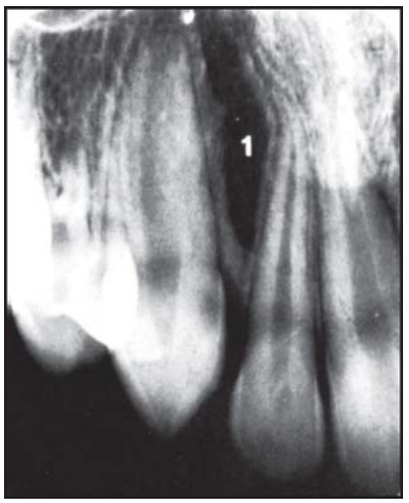


Fig. 17.10: 1. Is the lateral fossa, which may be misdiagnosed as a globulo maxillary cyst

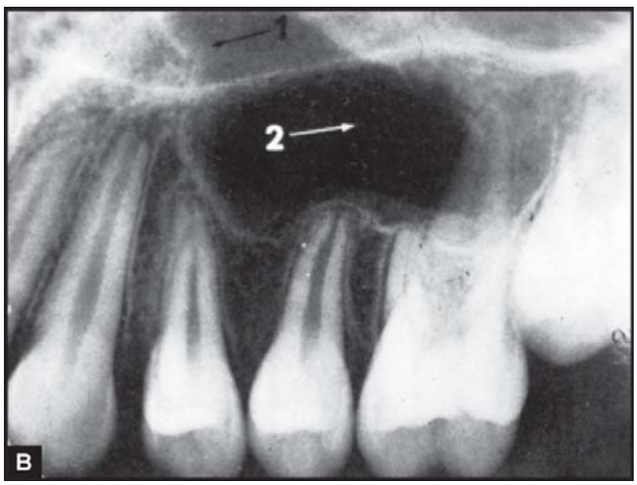


Fig. 17.11B: 1- nasal fossa, 2- maxillary sinus

The lateral walls of the nasal cavity are formed by the ethmoidal bone and the maxillae.

On the radiograph it appears as:

- A large radiolucent area above the maxillary incisors.

6. *Nasal Septum* (Figs 17.11A ,17.12):
It is a vertical bony wall or partition that divides the nasal cavity into the right and left nasal fossae. It is formed by two bones, the vomer and a portion of the ethmoid bone, and cartilage.

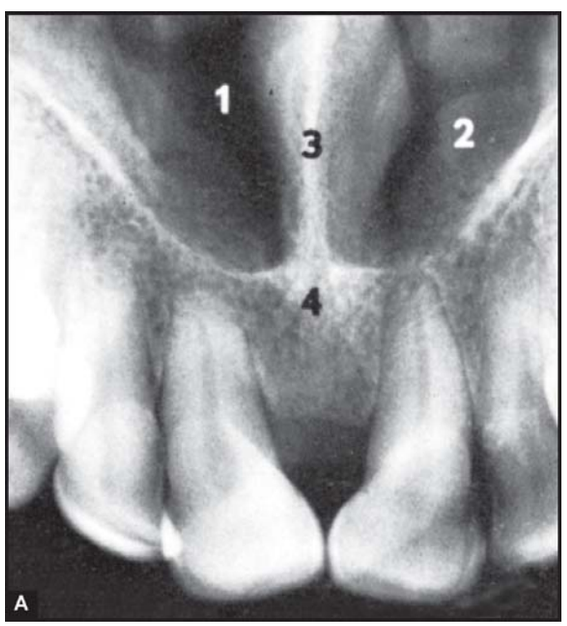


Fig. 17.11A: 1. The nasal fossa, 2. inferior turbinates, 3. nasal septum, 4- anterior nasal spine

On the radiograph it appears as

- A vertical radiopaque partition that divides the nasal cavity.
- The nasal septum may be superimposed over the median palatal suture.

7. *Floor of the Nasal Cavity* (Figs 17.13A and B):
It is a bony wall formed by the palatal process of the maxilla and the horizontal portions of the palatine bones.

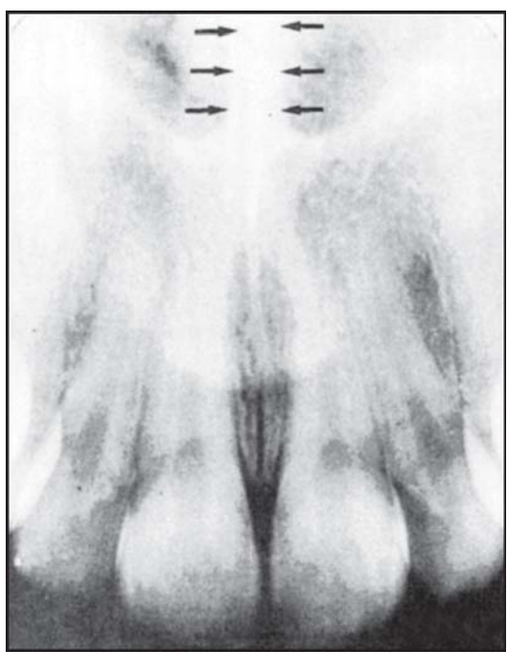


Fig. 17.12: The nasal septum appears as a radiopaque partition that divides the nasal cavity

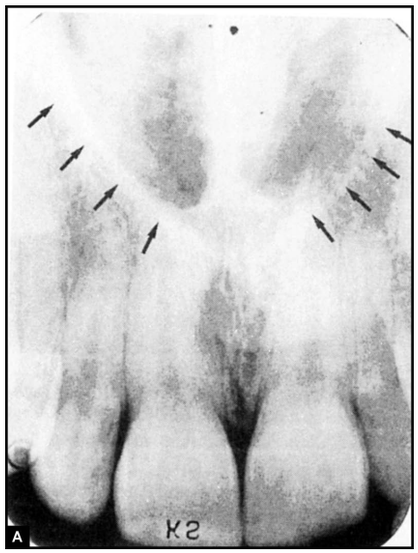


Fig. 17.13A: The nasal cavity appears as a large radiolucent area above the apices of the maxillary central incisors

The floor is made of dense cortical bone and defines the inferior border of the nasal cavity.

On the radiograph it appears as

- A dense radiopaque band above the maxillary incisors.

8. *Anterior Nasal Spine* (Figs 17.11A and 17.14):
It is a sharp projection of the maxilla located at the anterior and inferior portion of the nasal cavity.

On the radiograph it appears as

- A V–shaped radiopaque area located at the intersection of the floor of the nasal cavity and nasal septum.

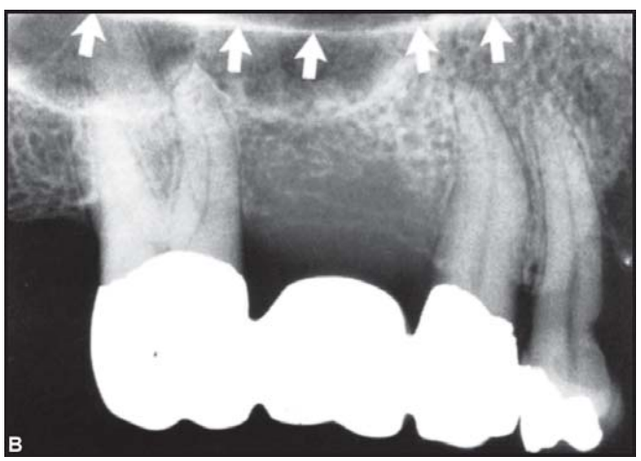


Fig. 17.13B: The floor of the nasal fossa extends posteriorly, superimposed with the maxillary sinus

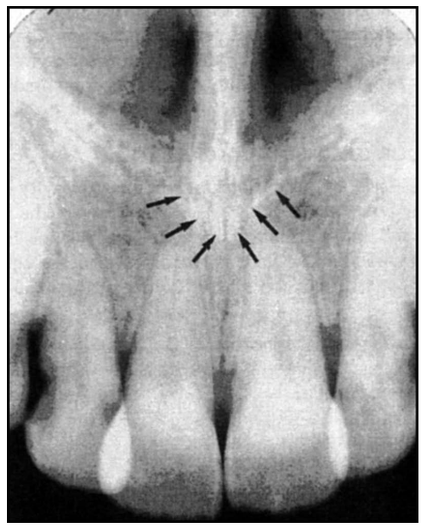


Fig. 17.14: The anterior nasal spine appears as a 'V' shaped radiopacity at the midline of the floor of the nasal cavity

9. *Inferior Nasal Conchae* (Fig. 17.15):
These are wafer thin, curved plates of bone that extend from the lateral walls of the nasal cavity, in the lower lateral portions.

On the radiograph they appear as

- A diffuse radiopaque mass or projection within the nasal cavity.

10. *Nasolacrimal Canal* (Fig. 17.16):
Is formed by the nasal and maxillary bones, running from the medial aspect of the antero-inferior border of

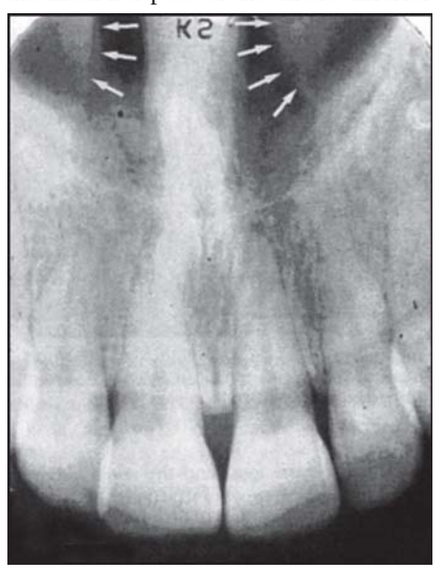


Fig. 17.15: The inferior nasal conchae appear as diffuse radiopacities within the nasal cavity

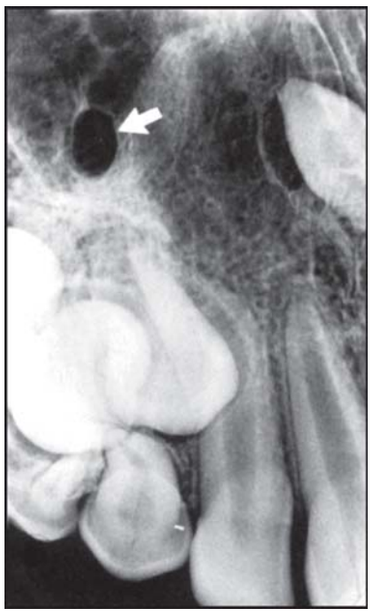


Fig. 17.16: The nasolacrimal canal is occasionally seen near the apex of the canine when a steep verticle angulation is used

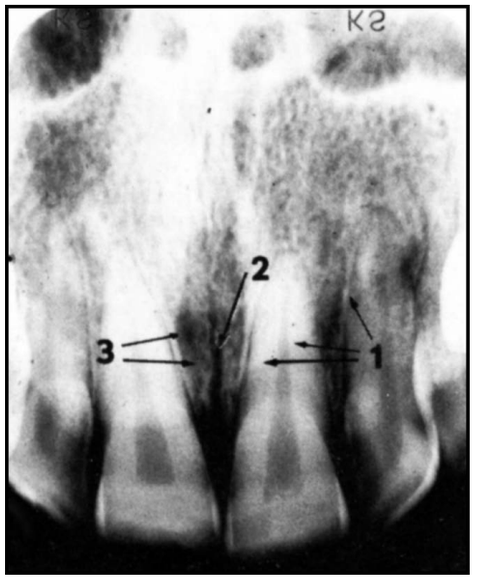


Fig. 17.17: 1. Shadow of nose, 2. Median palatal suture, 3. Incisive foramen

the orbit inferiorly to drain under the inferior conchae of the nasal cavity.

On the radiograph it appears as

- A well-defined slightly ovoid radiolucency, just above the apex of the maxillary canine, when a steep vertical angulation is used.
- It is seen more routinely on the maxillary occlusal projections.

11. *Nose* (Fig. 17.17):
    The soft tissue of the nose is frequently seen in the projections of the maxillary central and lateral incisors, superimposed on the roots of these teeth. The image of the nose has a uniform, slightly opaque appearance with a sharp border. Sometimes, the radiolucent nares may be identified.
12. *Nasolabial Fold* (Fig. 17.18):
    This is an oblique line demarcating a region that appears to be covered by a veil of slight radiopacity frequently seen in the premolar region. The line of contrast is sharp, and the area of increased radiopacity is posterior to the line. The line is the nasolabial fold, and the opaque veil is the thick cheek tissue superimposed on the teeth and the alveolar process. The image of the fold becomes more prominent with age.
13. *Maxillary Sinus* (Figs 17.11B and 17.19A):
    These are paired three sided pyramidal cavities of bone within the maxilla. They are located above the maxillary premolar and molar teeth. Its three sides include; the superior wall forming the floor of the orbit, anterior wall extending above the premolars and posterior bulging above the molar teeth and maxillary tuberosity. Rarely does the sinus extend beyond the canine. The sinus at birth is the size of a small pea, but in adults it may extend to include interdental bone, molar furcation areas or the maxillary tuberosity region.

    On the radiograph it appears as

    - A radiolucent area located above the apices of the maxillary molars.
    - The borders of the maxillary sinus are composed of dense cortical bone and appears as a radiopaque line.

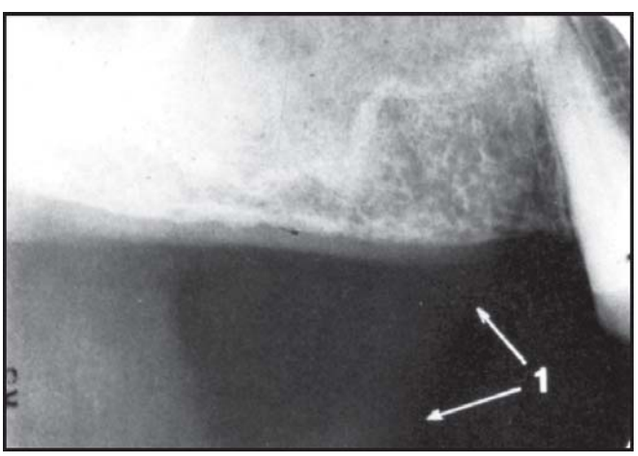


Fig. 17.18: The nasolabial fold

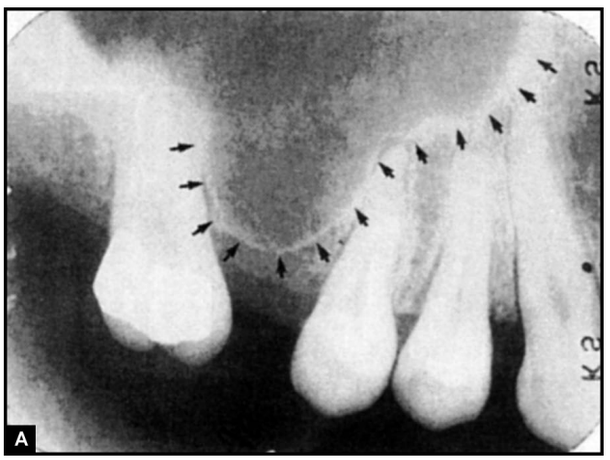


Fig. 17.19A: The maxillary sinus appears as a radiolucent area above the maxillary posterior teeth

ii. Septa within the maxillary sinus (Fig. 17.19B): These are bony projections or partitions that appear to divide the sinus into compartments, their presence and number varies from person-to-person.

On the radiograph they appear as

- Radiopaque lines with in the sinus.

ii. Nutrient canals within the maxillary sinus (Fig. 17.19C): These are tiny tube like passages through the bone that contain blood vessels and nerves that supply the maxillary teeth and interdental areas.

On the radiograph they appear as:

- A narrow radiolucent band bounded by two thin radiopaque lines.

When the rounded sinus floor dips between the buccal and palatal molar roots and is medial to the premolar roots, the projection of the apices is superior to the floor, and this appearance conveys the impression that the roots project into the sinus cavity, which is an illusion (Fig. 17.19D).

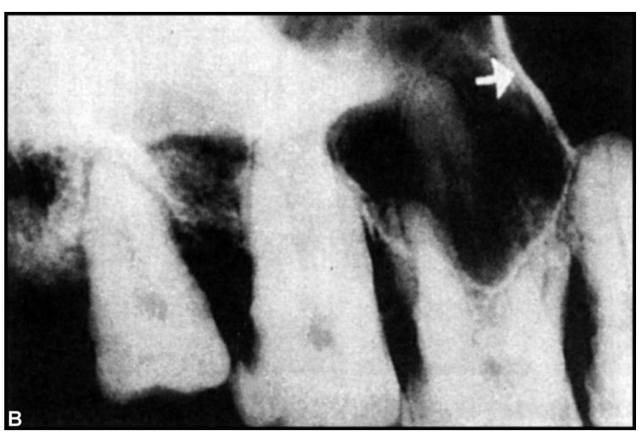


Fig. 17.19B: Septa within the maxillary sinus appear as radiopaque lines

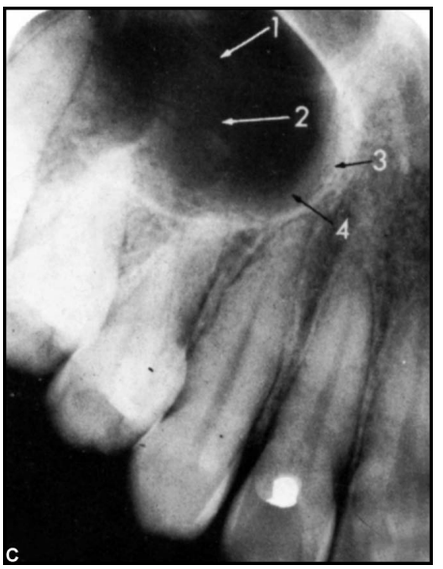


Fig. 17.19C: 1. Nutrient canal, 2. Maxillary sinus, 3. The cortical plate, 4. Maxillary antral mucosa

14. Inverted "Y" (Figs 17.20A and B):

This refers to the intersection of the maxillary sinus and the nasal cavity as seen on the radiograph.

On the radiograph it appears as

- A radiopaque upside down "Y" formed by the intersection of the floor of the nasal fossa and the anterior border of the maxillary sinus.
- The inverted Y is usually located above the maxillary canine.

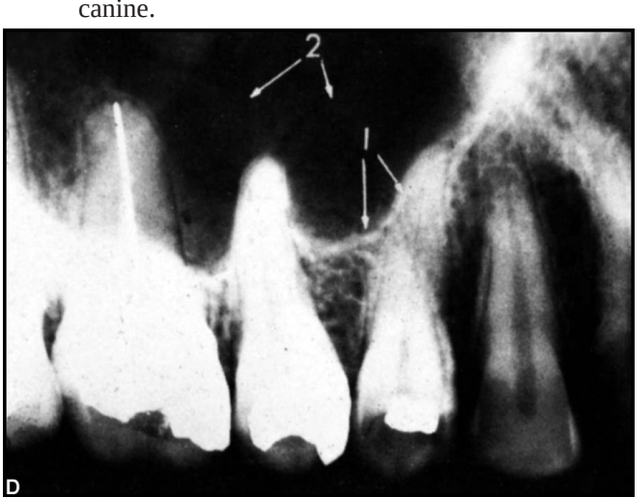


Fig. 17.19D: 1. The floor of the maxillary sinus, 2. The vascular canals

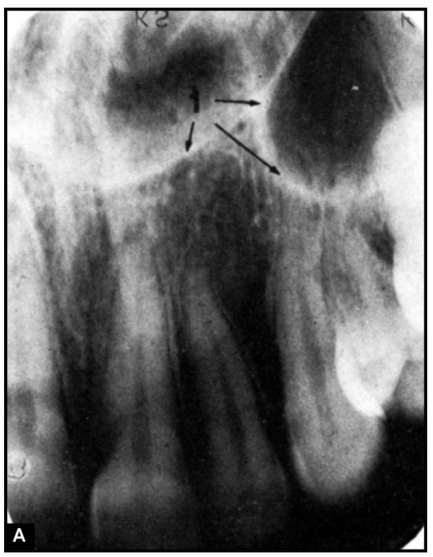


Fig. 17.20A: The floor of the nasal fossa and the maxillary sinus resemble the arms of the letter 'Y' and the bony walls separating the two structures resembles the leg of that letter

15. *Maxillary Tuberosity* (Fig. 17.21):
    This is a rounded prominence of bone which extends posterior to the third molar region. Blood vessels and nerves to the posterior teeth enter the maxilla from this region.
    On the radiograph it appears as
    - A radiopaque bulge posterior to the third molar region.
16. *Pterygoid Plates* (Figs 17.22A and B):
    The medial and lateral pterygoid plate lies immediately posterior to the tuberosity of the maxilla.

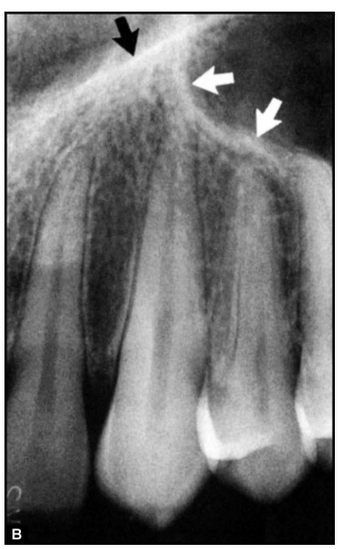


Fig. 17.20B: The anterior wall of the maxillary sinus (white arrows) crosses the floor of the nasal fossa (black arrow)

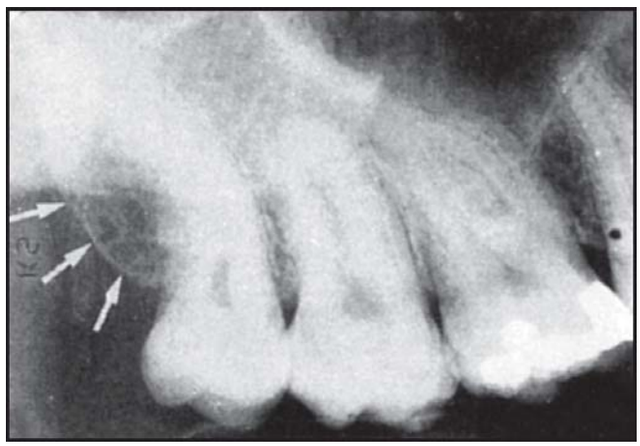


Fig. 17.21: The maxillary tuberosity appears as a radiopaque bulge distal to the third molar region

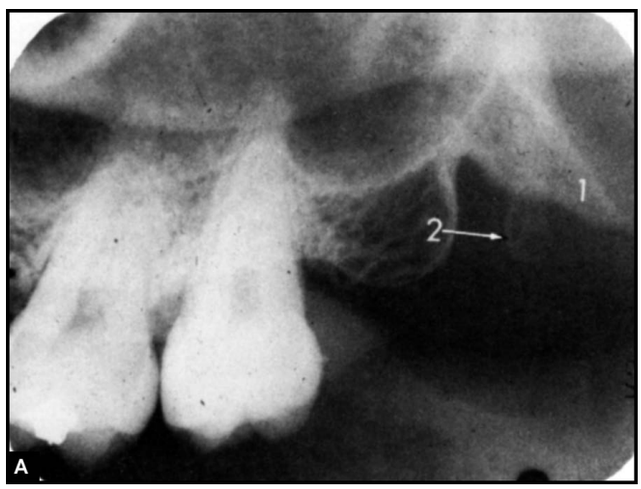


Fig. 17.22A: 1. The lateral plate of the pterygoid process, 2. The medial plate of the pterygoid process

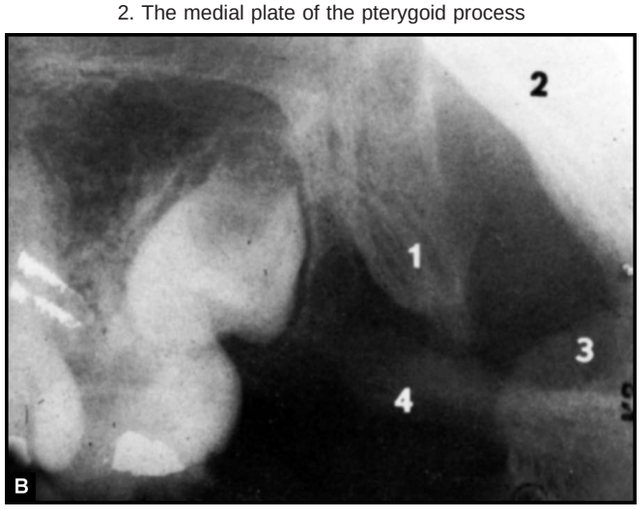


Fig. 17.22B: 1. Pterygoid complex, 2. Temporal bone, 3. Mandibular condyle, 4. Zygomatic arch

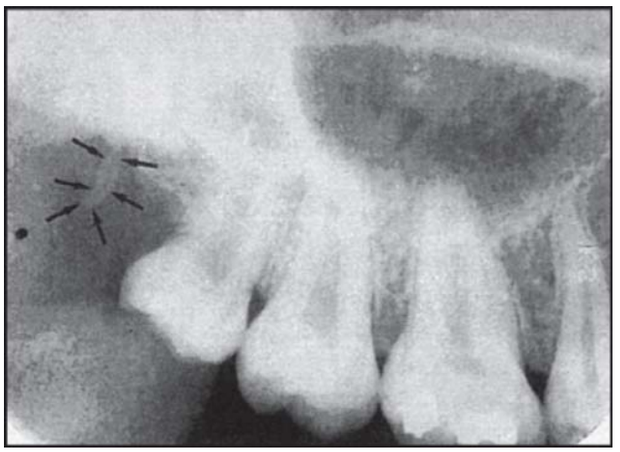


Fig. 17.23: The hamulus appears as a hook-like radiopacity distal to the maxillary tuberosity area

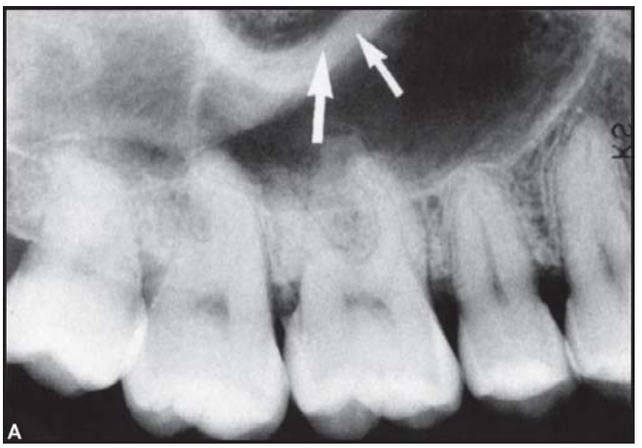


Fig. 17.24A: The zygomatic process of the maxilla protrudes laterally from the maxillary sinus wall, here it appears to be small with thick borders or as in 17.24B

On the radiograph they appear as

- A single radiopaque homogenous shadow without any evidence of trabeculation.
- It may not be seen on all radiographs.

17. *Hamulus (Hamular Process)* (Figs 17.22 A, 17.23):
It is a small hook-like projection of the bone extending from the medial pterygoid plate of the sphenoid bone. It is located posterior to the maxillary tuberosity process.
On the radiograph it appears as
- A radiopaque hook like projection posterior to the maxillary tuberosity area.
- The length, shape and density is variable.

18. *Zygomatic Process of the Maxilla* (Figs 17.24A to C):
It is the bony process of the maxilla that articulates with the zygoma, and is composed of dense corticated bone.
On the radiograph it appears as
- A "J" or "U" shaped radiopacity located superior to the maxillary first molar region. (Fig. 17.24D)

19. *Zygoma (Zygomatic Bone, Malar or Cheek Bone)* (Fig. 17.25A and B):
This articulates with the zygomatic process of the maxilla and is made of dense corticated bone.
On the radiograph it appears as:
- A diffuse radiopaque band extending posteriorly from the zygomatic process of the maxilla.

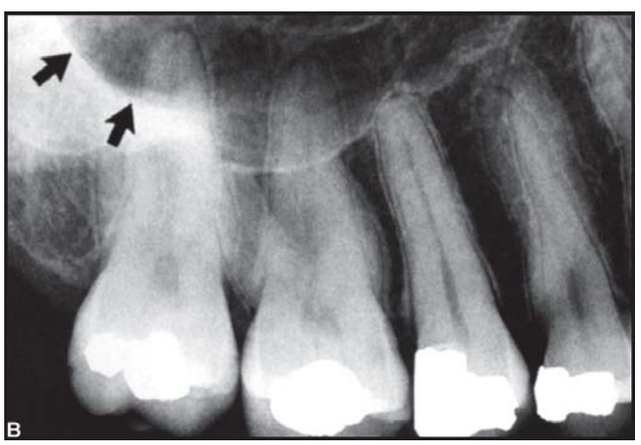


Fig. 17.24B: The zygomatic process appears large with thin borders

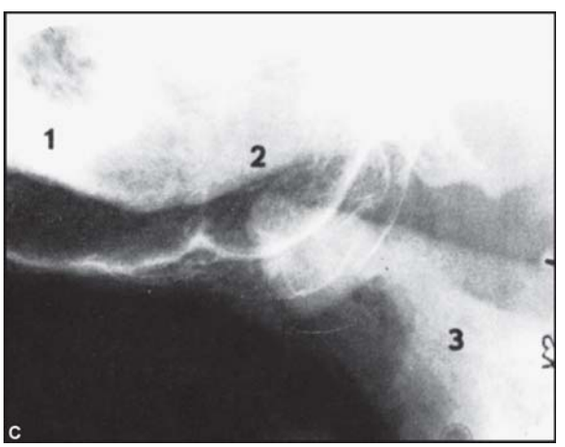


Fig. 17.24C: 1. The zygomatic process (malar process), 2. The zygomatic arch, 3. The coronoid process of the mandible

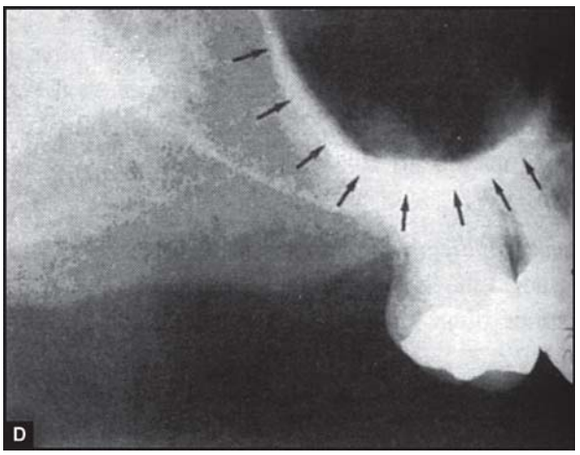


Fig. 17.24D: The zygomatic process of the maxilla appears as a 'J' or 'U' shaped radiopacity superior to the maxillary molars

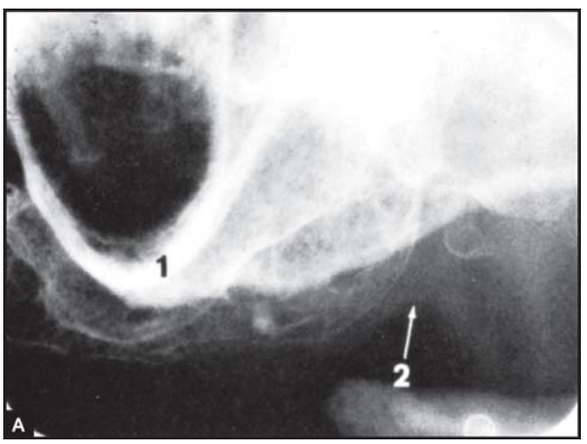


Fig. 17.25A: 1. The zygomatic process (malar process), 2. The soft tissue shadow of the hamular notch

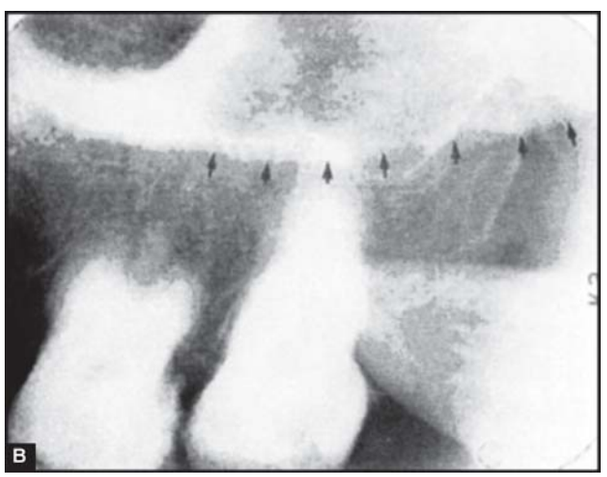


Fig. 17.25B: The zygoma appears as a diffuse radiopaque band that extends distally from the zygomatic process of the maxilla

Mandible

The mandible or the lower jaw is the largest and strongest bone of the face. It can be divided into three parts:

i. The ramus which is the vertical portion of the mandible, found posterior to the third molar. The mandible has two rami, one on each side.
ii. The body which is the horizontal "U"-shaped portion of the mandible which extends from one ramus to the other.
iii. Alveolar process which is that portion of the mandible that encases and supports the teeth.

1. *Genial Tubercules (Mental Spine)* (Fig. 17.26):
   These are tiny bumps of bone on the lingual side of the mandible, approximately in the midline, that serve as attachment for the genioglossus and the geniohyoid muscles.
   On the radiograph they appear as
   - Ring shaped radiopacities below the apices of the mandibular incisors.
2. *Lingual Foramen* (Fig. 17.27):
   Is a tiny opening in the bone located on the internal surface of the mandible, near the midline and surrounded by the genial tubercules.
   On the radiograph it appears as
   - A small radiolucent dot inferior to the apices of the mandibular incisors.
3. *Nutrient canals* (Fig. 17.28):
   These are tube like passages through the bone that contain nerves and blood vessels that supply the teeth. Inter dental nutrient canals are seen more in the anterior mandible.
   On the radiograph they appear as:
   - Vertical radiolucent lines.
   - These are more prominent in the anterior region and in the edentulous mandible.
4. *Mental Ridge* (Fig. 17.29):
   This is a linear prominence of cortical bone, located on the external surface of the anterior portion of the mandible, from the premolar to the midline and slopes silghtly upwards.
   On the radiograph it appears as
   - A thick radiopaque band that extends from the premolar to the incisor region.
   - It may appear superimposed on the mandibular anterior teeth.

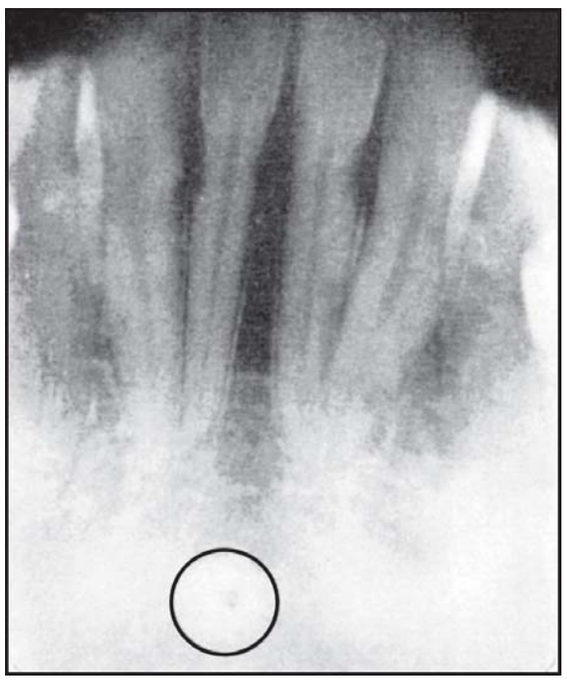


Fig. 17.26: The genial tubercules appear as a ring shape radiopacity

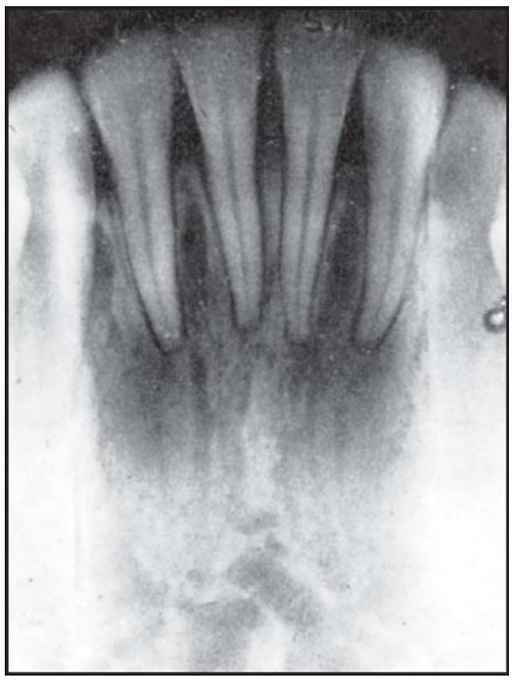


Fig. 17.28: Nutrient canals

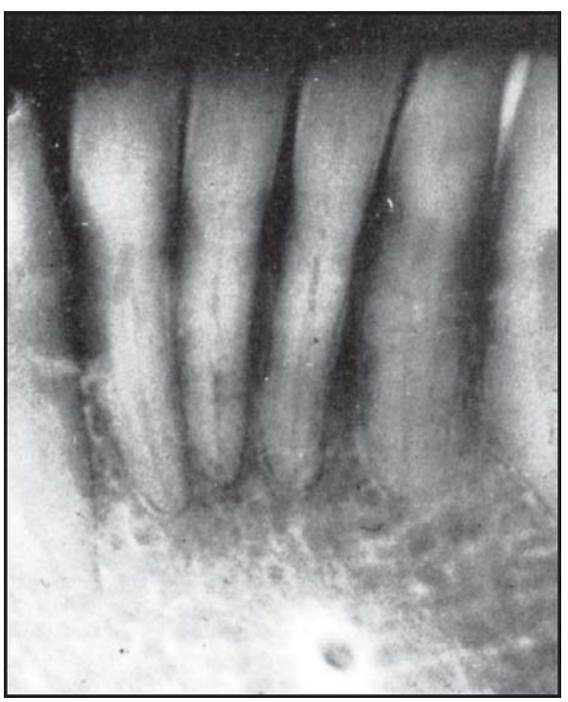


Fig. 17.27: The lingual foramen

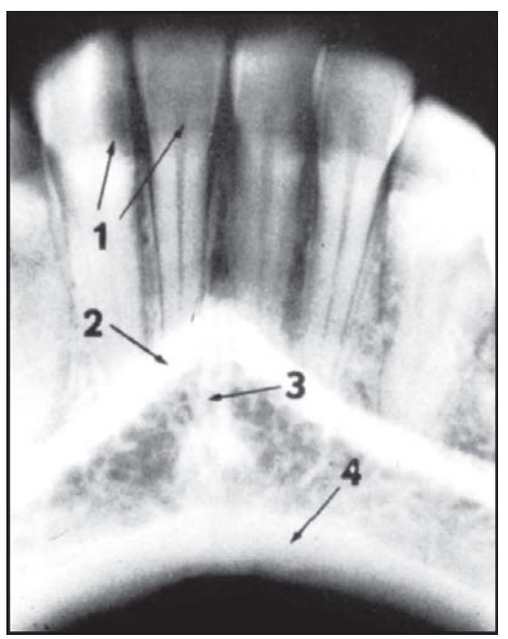


Fig. 17.29: 1. The lower lip line, 2. The mental ridge, 3. Lingual canal, 4. The cortical plate of the lower border of the mandible

5. *Mental Fossa* (Fig. 17.30):
   This is a scooped out depressed area of the bone located on the external surface of the anterior mandible. It is located above the mental ridge in the mandibular incisor region.
   On the radiograph it appears as
   - A radiolucent area above the mental ridge.
   - The appearance varies and is determined by the thickness of the bone in the anterior region.
6. *Mental Foramen* (Fig. 17.31A and B):
   It is an opening in the bone located on the external surface of the mandible, in the region of the mandibular premolars. Blood vessels and nerves that supply the lower lip exit through the mental foramen.
   On the radiograph it appears as:
   - A small ovoid or round radiolucent area located in the apical region of the premolars.
   - It is frequently misdiagnosed as a periapical lesion because of its apical location.
7. *Symphysis* (Fig. 17.32):
   The mandibular symphysis is the suture in the midline of the mandible. This suture fuses by the end of the first year of life, after which it is not radiographically apparent.

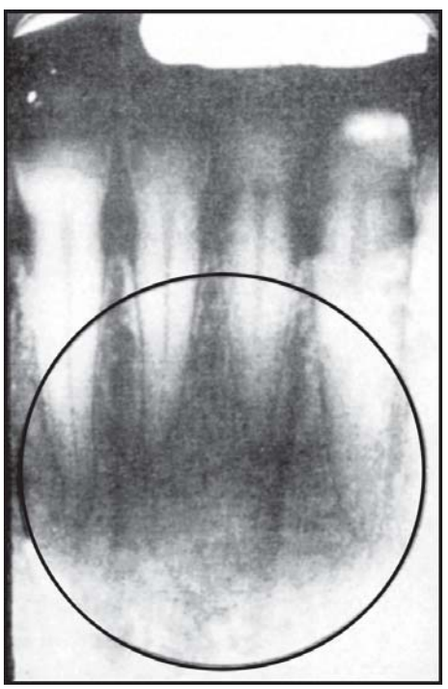


Fig. 17.30: The mental fossa appears as a radiolucent area above the mental ridge

Fig. 17.31A: 1. The mental foramen at the apex of the premolar, 2. Submandibular fossa

   On the radiograph it appears as:
   - A radiolucent line through the midline of the jaw.
8. *Mylohyoid Ridge* (Fig. 17.33):
   This is a linear prominence of the bone located on the internal surface of the mandible, extending from the molar region downwards and forward towards the lower border of the mandibular symphysis. It serves as an attachment for the mylohyoid muscle.
   On the radiograph it appears as:
   - A dense radiopaque band that extends downwards and forward from the molar region.

Fig. 17.31B: The mental foramen. There has been a lot of bone resorption so that the mental foramen now appears to be on the occlusal surface of the mandible

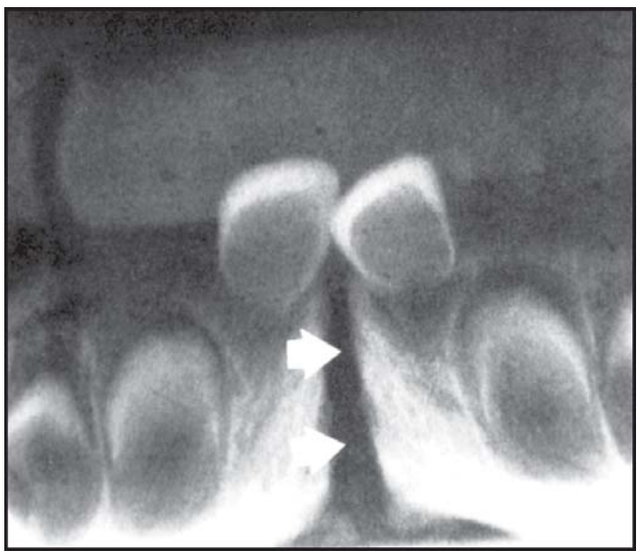


Fig. 17.32: Mandibular symphysis in a new born infant (bilateral supernumerary primary incisors present adjacent to it)

- It usually appears more prominent in the molar region and may be superimposed over the roots of the mandibular teeth.
- It may appear continuous with the internal oblique ridge.

9. *Internal Oblique Ridge (Internal Oblique Line)* (Figs 17.34A and B):
   This is a linear prominence of bone located on the internal surface of the mandible extending downwards and forwards from the ramus. It may end in the region of the third molar or it may continue on as the mylohyoid ridge.

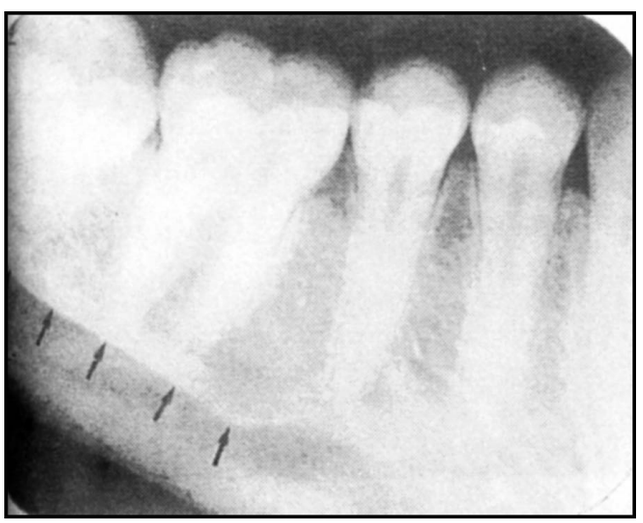


Fig. 17.33: The mylohyoid ridge appears as a radiopaque band in the mandibular molar region

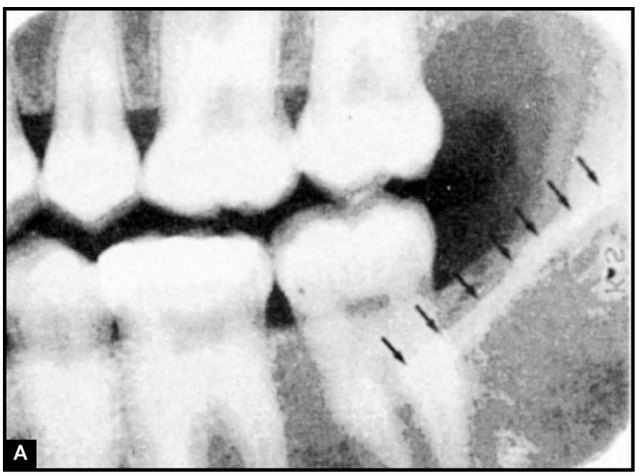


Fig. 17.34A: The internal oblique ridge appears as a radiopaque band

On the radiograph it appears as

- A radiopaque band that extends downwards and forward from the ramus.
- Depending on the technique used the internal and external oblique ridge may appear superimposed on one another. When the ridges appear separate, then the superior radiopaque band is the external oblique ridge and the inferior radiopaque band is the internal oblique ridge.

10. *External Oblique Ridge (External Oblique Line)* (Figs 17.35 A and B):
    It is a linear prominence of bone located on the external surface of the body of the mandible. The anterior border of the ramus ends in the external oblique ridge.

Fig. 17.34B: 1. Internal oblique ridge
2. Submandibular fossa

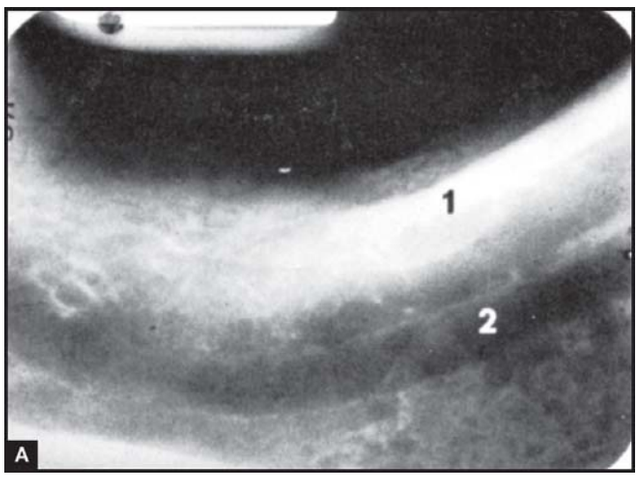


Fig. 17.35A: 1. The external oblique ridge, 2. The mandibular canal

On the radiograph it appears as

- A radiopaque band extending downwards and forwards from the anterior border of the ramus of the mandible.
- It typically ends in the mandibular third molar region.

11. *Mandibular canal* (Figs 17.35A and 17.36):
It is a tube-like passage through the bone that travels the length of the mandible. It extends from the mandibular foramen to the mental foramen and houses the inferior alveolar nerve and the blood vessels.

On the radiograph it appears as

- A radiolucent band, outlined by two thin radiopaque lines that represent the cortical walls of the canal.

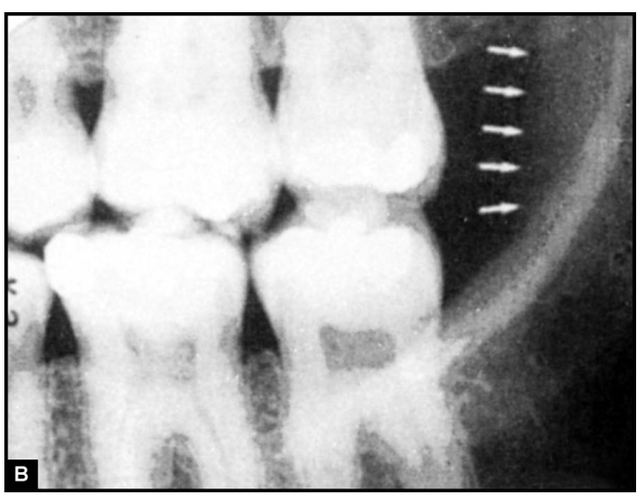


Fig. 17.35B: The external oblique ridge appears as a radiopaque band

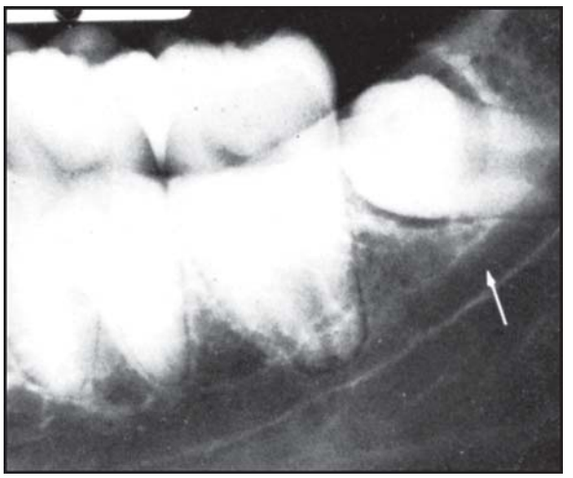


Fig. 17.36: The mandibular canal

- It may appear below or superimposed on the mandibular molar teeth.

12. *Inferior Border of the Mandible* (Fig. 17.37):
As the name suggests is the lower border of the mandible. It is rarely seen on the periapical projections.
On the radiograph it appears as

- A dense radiopaque band of bone.

13. *Coronoid Process* (Figs 17.24C and 17.38):
It is a marked prominence of bone on the anterior ramus of the mandible. It is the site for attachment of the muscles of mastication.

On the radiograph it appears as

- A triangular radiopacity superimposed over or inferior to the maxillary tuberosity region.

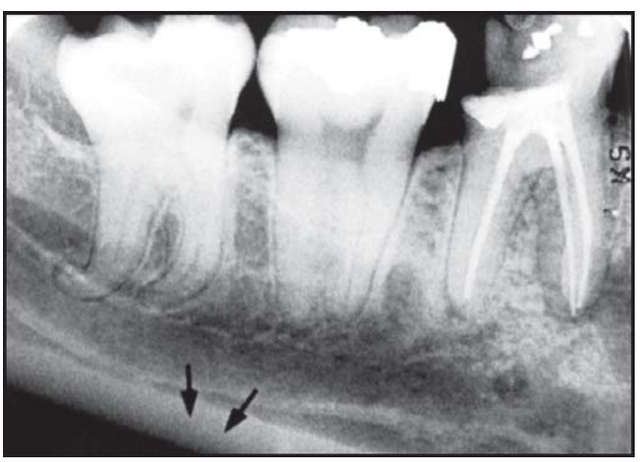


Fig. 17.37: The inferior border of the mandible is seen as a dense, broad radiopaque band

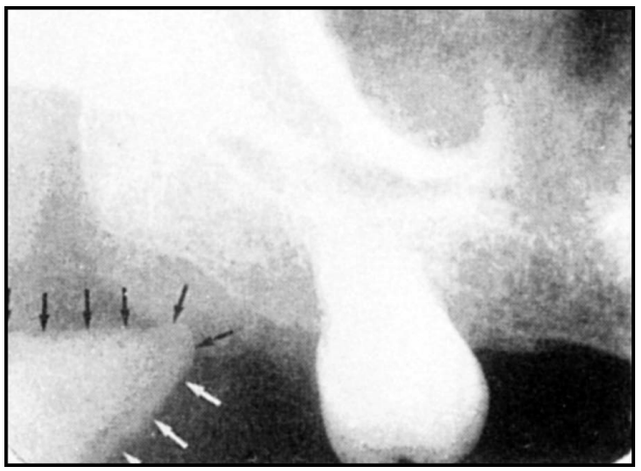


Fig. 17.38: The coronoid process appears as a triangular shaped radiopacity

- It is seen on the maxillary molar periapical radiograph, and not a mandibular periapical radiograph.

14. *Submandibular Fossa (Mandibular Fossa or Submaxillary Fossa)* (Figs 17.31A, 17.34B):
    It is a scooped out depressed area of the bone located on the internal surface of the mandible inferior to the mylohyoid line. It houses the submandibular salivary gland.
    On the radiograph it appears as
    - A radiolucent area in the molar region below the mylohyoid ridge.
    - Few bony trabeculae are seen in this region.

Other Restorative Materials

Restorative materials vary in their radiographic appearance, depending primarily on:

i. Thickness.
ii. Density.
iii. Atomic number.

Various Restorative Materials recognized on an intraoral radiographs are: (Figs 17.39A to G)

1.	Silver amalgam	:	Completely radiopaque.
2.	Gold	:	Completely radiopaque
3.	Stainless steel	:	Completely radiopaque
4.	Calcium hydroxide base	:	Generally radiopaque, but may be radiolucent
5.	Gutta percha	:	Radiopaque.

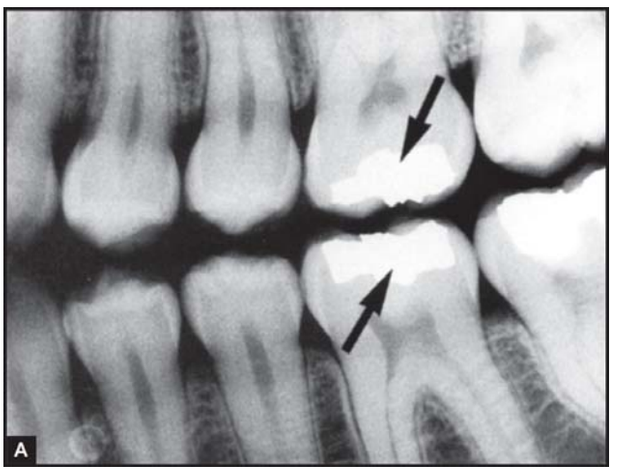


Fig. 17.39A: Radiopaque amalgam restorations

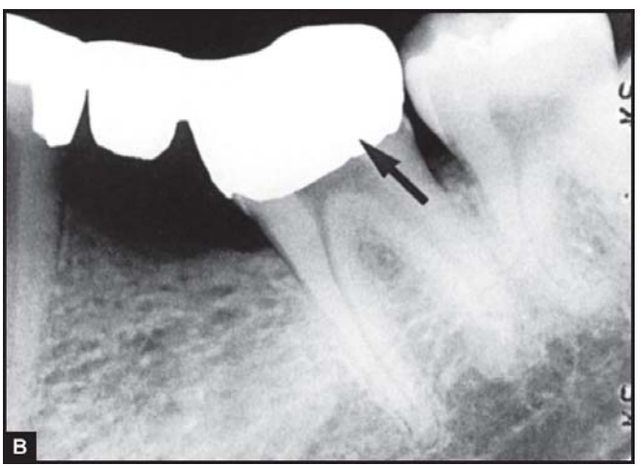


Fig. 17.39B: A cast gold crown, appearing completely radiopaque (arrow), serves as the terminal abutment of a bridge

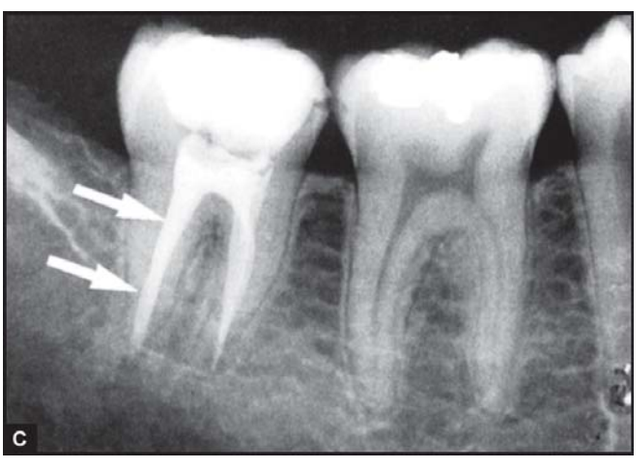


Fig. 17.39C: Gutta-percha (arrows) is a radiopaque material used in endodontic therapy

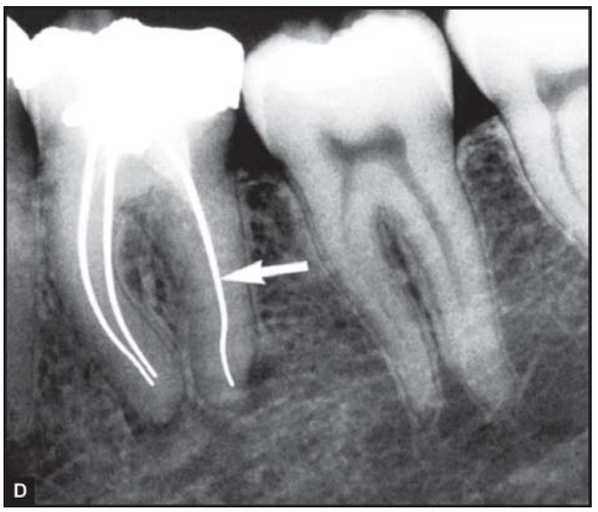


Fig. 17.39D: Silver points also appear radiopaque

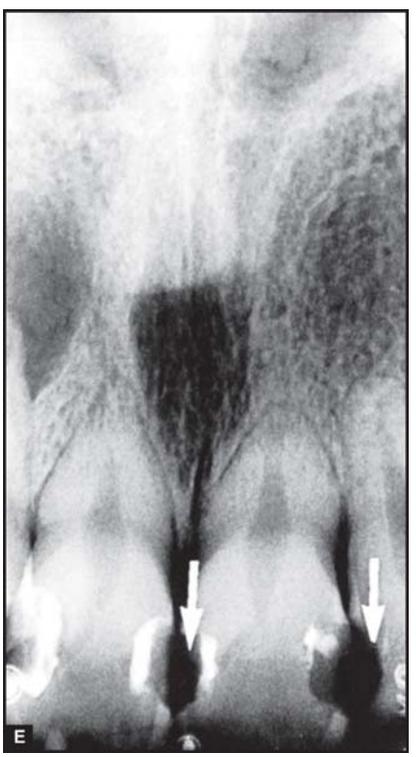


Fig. 17.39E: Radiolucent silicate restorations (arrows)

Fig. 17.39F: Porcelain appears radiolucent (arrow) over metal coping

Fig. 17.39G: Orthodontic appliances have a characteristics radiopaque appearance

6. Silver points : Completely radiopaque.
7. Silicates : Completely radiolucent.
8. Composites : Appears radiolucent, may occasionally be radiopaque.
9. Porcelain : Appears radiolucent.

BIBLIOGRAPHY

1. Brand RW, Isselhard DE. Osteology of the skull. In anatomy of Orofacial Structures, 4th ed. St. Louis, CV Mosby, 1990; 117-113.
2. Goaz PW, White SC. In oral radiology, principles and interpretation, 3rd ed. St Louis, CV Mosby, 1994.
3. Haring JI, Lind LJ. Normal anatomy, in Radiographic interpretation for dental hygienist, Philadelphia. WB Saunders, 1993; 25-81.

18

Basics in Interpreting Radiographs

Radiographic interpretation is an essential part of diagnostic process. The ability to recognize what is revealed by a radiograph enables a dental professional to play a vital role in the detection of diseases, lesions and condition of the jaw that cannot be identified clinically.

One has to define the difference between:

Interpretation: Refers to an explanation of what is viewed on the radiograph.

Diagnosis: Refers to the identification of disease by examination or analysis.

In dentistry, a diagnosis is made by the dentist after a through review of medical history, dental history, clinical examination, radiographic examination, and clinical or laboratory tests.

For accurate diagnostic information to be interpreted, there should be ideal viewing conditions, like:

- Reduced ambient light in the viewing room.
- Intra oral radiographs should be mounted in a film holder.
- Light from the view box should be of equal intensity across the viewing surface.
- The size of the view box should accommodate the size of the film.
- An intense light source is essential for evaluating dark regions of the film.
- A magnifying glass allows detailed examination of small regions of the film.

In order to correctly and competently interpret a radiograph, the dental professional must be confident in identification and recognition of the normal anatomical structures and their variations seen in the radiographs taken of the various regions.

For Intra Oral Images:

- Examination of the periapical image should be done before that of the bitewing image.
- Identify the normal anatomical landmarks of that region.
- Examine the character of the trabeculae bone, the density, size, etc.
- Compare the same areas on adjacent images and those on corresponding area on images of the other side.
- Examine the bone of the alveolar process;
  i. Height.
  ii. Cortication.
  iii. Erosion.
  iv. Trabeculae pattern of the alveolar bone.
- Examine each tooth in sequence;
  i. The crown for normal development of enamel, caries, especially inter proximal areas.
  ii. Check restorations for recurrent caries.
  iii. Examine the pulp chamber for size and contents.
  iv. Examine roots for shape, developmental anomalies and external resorption.
- Uniformity of width of the periodontal ligament space.
- The continuity of the lamina dura around the entire length of the root.
- The most common abnormalities found in bone are either,
  i. radiolucent lesions
  ii. radiopaque lesions.

  which need to be analyzed.

For Extra Oral Images:

- A through understanding of the appearance of the normal anatomical structures on the image.

  The absence of a normal anatomic structure may be the most important finding on the image.

- Examination and identification of normal soft tissues shadows.
- Evaluation of the dentition and supporting bone.
- The most common pathologies are intraosseous lesions which should be analyzed.

Systemic Sequence for Viewing a Dental Panoramic Tomograph

A. General overview of the entire film.
   - Note the chronological and developmental age of the patient.
   - Trace the outline of all normal anatomical shadows and compare their shape and radio density.

B. The teeth
   - Number of teeth present.
   - Stage of development.
   - Position.
   - Condition of the crowns.
     – Caries.
     – Restorations.
   - Condition of the roots.
     – length
     – fillings
     – resorption
     – crown/root ratio

C. The apical tissues.
   - Integrity of lamina dura.
   - Any radiolucency or radiopacity associated with the apices.

D. The periodontal tissues.
   - The width of the periodontal ligament.
   - The level and quality of crestal bone.
   - Any vertical or horizontal bone loss.
   - Any furcation involvements.
   - Any calculus deposits.

E. The body and the ramus of the mandible.
   - Shape.
   - Outline.
   - Thickness of the lower border.
   - Trabeculae pattern.
   - Any radiolucent or radiopaque areas.
   - Shape of the condylar heads.

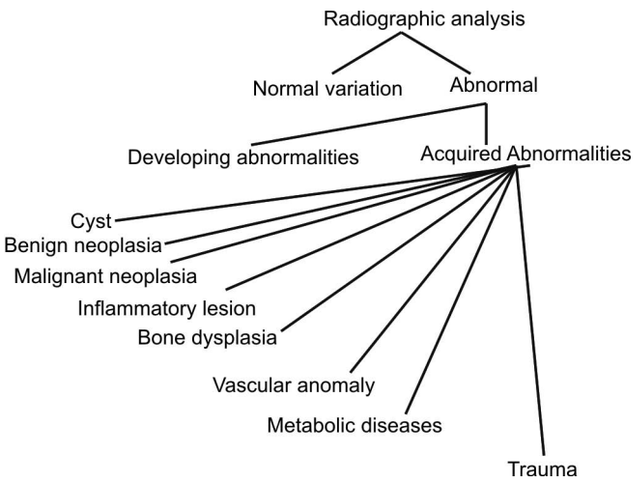
F. Other structures.
   - The antra
     – outline of the floor, and anterior and posterior walls
     – radiodensity.
   - Nasal cavity.
   - Styloid process

Analysis of Intraosseous Lesions

There are two basic approaches:

1. *Aunt minnie method*: This involves trying to match the radiographic image with a mental picture or with an image in a favourite text book.
2. *Five step, step-by-step analysis method*: This helps ensure recognition and collection of all the information contained in the image and in turns improves the accuracy of the interpretation. (Flow Chart 18.1)

Flow Chart 18.1: An algorithm representing the diagnostic process that follows evaluation of the radiographic features of an abnormality



Analysis of Intraosseous Lesions

Step 1: Localize the abnormality.

i. Localized to a specific region
   a. Unilateral- more likely to be a pathology.
   b. Bilateral- more likely to be variation of normal structures.

ii. Generalized
   a. Metabolic disturbance.
   b. Endocrinal disturbance.

iii. Position in the jaws.
   a. Within the jaws.
   b. In the soft tissue.

iv. Position of the Epicenter.
   - Coronal to the tooth—composed of odontogenic epithelium.
   - Above the inferior alveolar nerve—composed of odontogenic tissue.
   - Below the inferior alveolar nerve—unlikely to be composed of odontogenic tissue.

- Within the inferior alveolar nerve—composed of neural or vascular tissue.
- In the condylar region—cartilaginous lesions and osteochondromas.
- Within the maxillary antrum—not of odontogenic tissue.
- Grown into the antrum from the alveolar process—of odontogenic origin.

Some lesions have specific locations and epicenters:

- Central giant cell granuloma, the epicenter is located
  - Anterior to the first molars in the mandible
  - Anterior to the cuspid in the maxilla.
- Osteomyelitis occurs in the mandible and rarely in the maxilla.
- Periapical cemental dysplasia occurs in the periapical region of the teeth.

v. Number.
   a. Single.
   b. Multifocal
      eg. periapical cemental dysplasia
      odontogenic keratocyst
      metastatic lesions
      multiple myeloma leukemia infiltrations

vi. Size: There are few size restrictions for a particular lesion, but it may aid in differential diagnosis, eg. A dentigerous cyst is often larger than a hyperplasic follicle.

Step 2: Assess the Periphery and Shape.

A. Periphery

i. Well-defined: is one in which most of the periphery is well-defined.
   - Punched out border, is a sharp border with no apparent bone reaction in the adjacent region. e.g. multiple myeloma
   - Corticated margin, is a thin fairly uniform radiopaque line of reactive bone at the periphery e.g. cysts
   - Sclerotic margin, is a wide radiopaque border of reactive bone, not necessarily of uniform width e.g. periapical cemental dysplasia
   - Radiolucent line around radiopaque lesions, indicates a soft tissue capsule which may be in conjunction with a corticated periphery, e.g. odontomas, cementomas.

ii. Ill-defined: is one in which it is difficult to draw an exact delineation around most of an ill-defined periphery.
   - Blending border, it is ill-defined because of gradual transition between normal appearing bone trabeculae and abnormal appearing trabeculae of the lesion, eg. fibrous dysplasia, sclerosing osteitis.
   - Invasive border or permeative border, is usually associated with rapid growth. E.g. malignancy.

B. Shape: A lesion may have a particular shape or it may be irregular.
   - Circular or fluid filled, e.g. cyst.
   - Scalloped shape, this is a series of arcs or semi circles which may reflect the mechanism of growth. e.g. odontogenic keratocyst, benign tumors.

Step 3: Analyze the Internal Structure. (Table 18.1)

i. Radiolucent – e.g. air, fluid, soft tissue, bone marrow.
ii. Mixed – e.g. trabecular bone.
iii. Radiopaque – e.g. cortical bone, dentin, enamel, metal.

Important mixed density lesions;

- Orange peel or ground glass appearance as in fibrous dysplasia.
- Presence of septa (residual bone) may divide the internal structure into compartments (multilocular);
  - curved coarse septa, giving an internal pattern of soap bubble appearance e.g.—ameloblastoma, odontogenic keratocysts.
  - wipsy or granular septa seen in giant cell granuloma.
  - small straight septa, tennis racket appearance, as seen in odontogenic myxoma.
- Dystrophic calcification, is one which occurs in damaged soft tissue.
  - dense cauliflower like masses in soft tissue – calcified lymph nodes.
  - very delicate, particulate appearance of calcification may be seen in chronically inflamed cysts.
- Cementum may have a homogenous, dense, amorphorous structure and sometimes may be organized into round or oval shapes.
- Tooth structure, can be recognized by the organization into enamel, dentin and pulp chamber. Internal density will be greater than that of surrounding bone.

Step 4: Analyze the Effects of the Lesion on Surrounding Structures.

Evaluating the effects of the lesion on surrounding structures allows the observer to infer its behavior,

i. Teeth, lamina dura and periodontal membrane space.
   - Displacement of teeth; indicates a slow growing lesion.

     The direction of displacement is also significant,
     - lesion with an epicenter above the crown of the tooth, displace it apically, e.g. follicular cysts.

Table 18.1: Typical radiographic description of various oral lesions as seen on the radiograph

1.	Ball in hand appearance	Benign salivary gland tumors.
2.	Balloon like appearance	Follicular cysts.
		Aneurysmal bone cyst.
3.	Candlestick appearance	Pyknodysostosis
4.	Cart Wheel appearance	Central hemangioma
5.	Chalk-like appearance	Osteopetrosis (Marble Bone Disease)
		Hyperparathyroidism
		Pyknodysostosis
6.	Cherry blossom pattern	Sialograph of Sjögrens syndrome
7.	Codman's triangle	Osteosarcoma
8.	Cotton-wool appearance	Fibrous dysplasia
		Odontogenic fibroma
		Pagets disease
9.	Driven snow appearance	Pindborg's tumor (CEOT)
10.	Egg shell appearance	Ameloblastoma
		Multilocular cyst
11.	Filling defect	Salivary gland tumor
12.	Floating teeth appearance	Squamous cell carcinoma
		Malignant lymphoma
		Eosinophillic granuloma
		Osteomyelitis
		Periodontitis
		Papillon- Lefevre syndrome
13.	Ghost teeth	odontogenesis dysplasia
14.	Ground glass appearance	Fibrous dysplasia
		Ossifying fibroma
		Osteosarcoma
		Hyperparathyroidism
		Paget's disease
		Rickets
15.	Hair on end appearance	Thalessemia
		Sickle cell anemia
16.	Heart shaped radiolucency	Incisive canal cyst
17.	Honey comb appearance	Ameloblastoma
		Central hemangioma
		Dentigerous cyst
		Central giant cell granuloma
18.	Moth eaten appearance*	Squamous cell carcinoma.
		Malignant lymphoma
		Chronic osteomyelitis
19.	Mottled appearance	Fibrous dysplasia
		Ossifying fibroma
20.	Onion-peel appearance	Garre's osteomyelitis
		Eosinophilic granuloma
		Ewing's sarcoma
		Infantile cortical hyperostosis
		Osteogenic sarcoma
		Ossifying subperiosteal hematoma
21.	Orange peel appearance	Fibrous dysplasia
		Hyperparathyroidism
		Paget's disease
		Rickets
22.	Permeated appearance	Carcinoma of the gingiva
		Carcinoma of the maxilla
		Malignant lymphoma
23.	Pear shaped appearance	Globulomaxillary cyst
		Radicular cyst
24.	Pencil like appearance	Artheritic condyle
25.	Pressure type appearance	Carcinoma of the gingiva
26.	Punched out appearance	Multiple myeloma
27.	Sand like appearance	Adenoameloblastoma
		Gorlin's cyst
		Pindborg tumor
28.	Salt and pepper appearance	Hyperparathyroidism
29.	Scalloping pattern (margins)	Ddentigerous cyst
		Traumatic bone cyst
		Aneurysmal bone cyst
		Giant cell granuloma
30.	Shell teeth	Dentinogenesis imperfecta
31.	Soap bubble appearance**	Ameloblastoma
		Giant cell tumor
		Central hemangioma
		Aneurysmal cyst
32.	Spiked root	Malignant histiocytoma
		Burkitt tumor
33.	Spokes wheel appearance	Central hemangioma
34.	Sunray (burst) appearance	Osteosarcoma
		Ewing's sarcoma
35.	Tennis Racket appearance	Odontogenic myxoma
36.	Worm Eaten appearance*	Carcinoma
		Malignant lymphoma
		Chronic osteomyelitis

* Moth eaten appearance and worm eaten appearance are used interchangeably.
Moth eaten refers to a smaller circular cysts like radiolucencies of even sizes

** Soap bubble appearance refers to circular cyst like radiolucencies of various sizes, bigger than those in 'moth-eaten'

– lesions that start in the ramus, may push the teeth in an anterior direction, e.g. cherubism.
– lesions that grow in the papillae of the developing tooth, may push the tooth coronally, e.g. lymphoma, leukemia, langerhan's cell histiocytosis.

• Widening of the periodontal ligament space;
– Uniform or irregular
– Lamina dura is present or lost
– Orthodontic movement-uniform widening without loss of lamina dura
– malignancy-irregular widening with loss of lamina dura.

ii. Surrounding bone density and trabecular pattern.
The presence of reactive bone at the periphery, whether corticated or sclerotic signifies a slow benign growth.

iii. Inferior alveolar nerve and mental foramen.
• Superior displacement of inferior alveolar canal—fibrous dysplasia.
• Widening of the inferior alveolar canal with maintainence of cortical boundary—benign lesion of vascular or neural origin.
• Irregular widening with cortical destruction—malignant neoplasm in the canal.

iv. Outer Cortical Bone and Periosteal Reactions.
• Expanded bone with an outer cortical plate—slow growing lesion.
• Expanded bone without the cortical plate—rapidly growing lesion.
• Onion peel appearance, where the exudates from an inflammatory lesion lifts the periosteum off the surface of cortical bone and then stimulate periosteum to lay down new bone, and this process occurs more than once, inflammatory lesion and in rare malignant lesions (leukemia) and Langerhans cell histiocytosis.
• Some periosteal reactions are specific;
– Spiculated new bone formed at right angles to the outer cortical plate–
– Hair on end appearance, thalassemia, sickle cell anemia.
– Radiating pattern—osteogenic sarcoma.

Step 5: Formulate a Radiographic Interpretation.

Decision 1: Normal versus abnormal
Normal or variation from the normal does not require any treatment.

Decision 2: Developmental versus acquired
If the abnormality is developmental, then one need not do any further analysis.

Decision 3: Classification
If the abnormality is acquired then the next step is to classify it, into cyst, benign or malignant tumor, inflammatory lesion, bone dysplasia, vascular abnormalities, metabolic diseases or physical changes. At this step one should try to bring the clinical information into the decision process.

Decision 4: Ways to Proceed
• Any other radiographs.
• Biopsy.
• Put the patient under observation.

A Short Summary for Interpreting Common Pathologies Seen on the Radiograph

S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
1.	Dental Caries (Fig. 18.1)	
	i. Inter proximal bitewing	
	a. Incipient	– rl. involving less than ½ thickness of enamel "notch-like"
	b. Moderate	– rl. triangle with the broad base at the surface of the tooth, or a diffuse rl. or a combination of both
	c. Advanced	– rl. involving the entire enamel more than half the dentin and closely approximating the pulp. *D/D: cervical burn out*
	ii. Occlusal (periapical/ bitewing)	
	a. Incipient	– Fine gray shadow just under the DE junction.
	b. Moderate	– Broad based thin rl. zone in the dentin, with no apparent changes in the enamel.
	c. Severe	– Large rl.cy involving the enamel, dentin and involving the pulpal horns.

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
		D/D: "mach band" effect - due to the sharp difference in density between enamel and dentin, there may appear to be a more rl. region adjacent to the enamel. An optical illusion
	iii. Buccal/Lingual/ or Palatal (bitewing/ periapical)	– A round rl. area, surrounded by a uniform non carious region of enamel.
	iv. Root surface Caries (periapical)	– Ill-defined saucer like rl. at the CE junction. *D/D: cervical burn out*
	v. Recurrent Caries (bitewing/ periapical)	– Areas of increased rl. along the margins of restorations. restorative material may appear rl. or ro.
		Other Diagnostic Aids *Light Fluorescence* *Diagnodent* *Laser light* *Fibroptic Transillumination (FOTI)* *Electrical conductance Measurements (ECM)* *Ultra sound*
2.	Periodontal Disease (Figs 18.2A and B) (bitewing/periapical/OPG)	
	i. Early Periodontitis	– No apparent radiographic changes, areas of localized erosion of the alveolar crest and slight loss of alveolar bone height, loss of cortication.
	ii. Moderate Periodontitis	– Extensive vertical defects or generalized bone loss.
	a. Horizontal Bone Loss > Local > Generalized	Radiographs help to evaluate – Amount of bone present. – Condition of alveolar crest – Width of periodontal ligament space – Presence of calculus or poorly contoured fillings – Crown root ratio

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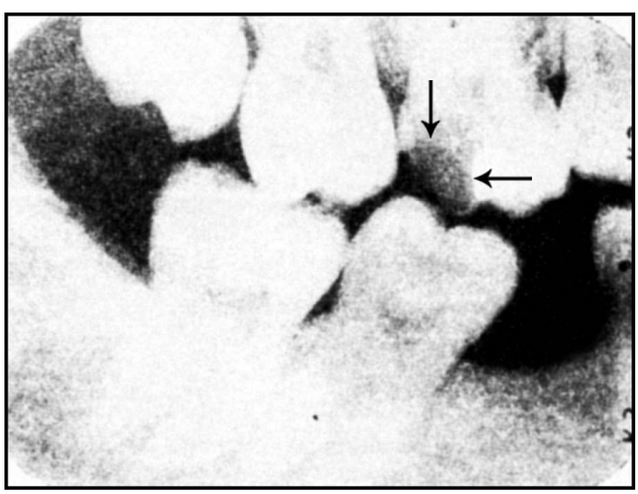

Fig. 18.1: Dental caries in maxillary first molar

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	b. Osseous Defects > Inter Proximal Craters > Proximal Intra Bony Defect > Interproximal Hemisepta > Inconsistent Bony Margins	– Bone loss in furcation area.
	iii. Advanced Periodontitis a. Osseous Deformities in furcation of multi rooted b. Alveolar dehiscence	– Extensive bone loss, furcation involvement producing an inverted "J" shadow
	iv. Periodontal Abscess	– rl. superimposed over the root of the tooth. *D/D: the bone destruction seen may be mistaken for* – *squamous cell carcinoma* – *eosinophillic granuloma (ice cream scoop appearance)* – *systemic diseases associated are diabetes mellitus, haematological disorders* *Other Diagnostic Aids* *clinical evaluation is a better method* *subtraction radiography* *xeroradiography*
3.	Dental Anomalies (Figs 18.3A to F) (periapical/OPG)	
	Supernumerary teeth Supplementary Missing teeth Macrodontia Microdontia	Smaller than normal teeth Additional teeth, having the same size as that of normal teeth.

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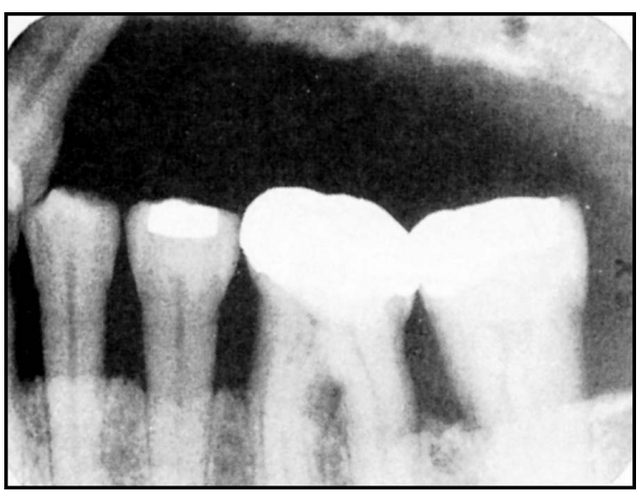

Fig. 18.2A: Horizontal bone loss

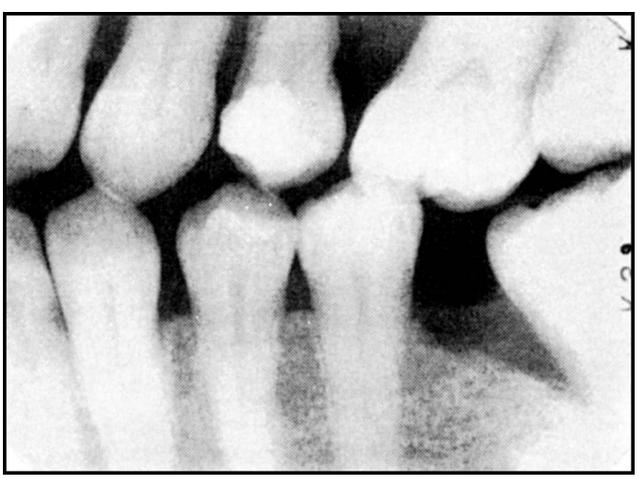

Fig. 18.2B: Vertical bone loss

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	Transposition	Tooth not in its usual position.
	Fusion	Nature and extend of fusion better seen on the radiograph.
	Concrescence	
	Gemination	Altered shape of the hard tissue and pulp chamber is seen.
	Taurodontism	Extension of a rectangular pulp chamber into an elongated body of the tooth.
	Dilaceration	Bending of the root, if apical end involved it may appear like a 'bulls eye'.
	Dens in dente	
	Dens evaginatus	
	Amelogenesis imperfecta	A square shape of crown, thin layer of enamel, low or absent cusps.
	Dentinogenesis imperfecta	Constriction of the cervical portion of the crown giving a 'bulbous appearance' Obliteration of the pulp chamber may be seen.
	Osteogenesis imperfecta	(Blue sclera), wormian bones, skeletal deformity.
	Dentin dysplasia	Type I roots are short, pulp chamber and canal completely obliterated, with periapical radiolucencies. Type II obliteration of the pulp chamber and reduction Caliber of root canals. 'Flame shaped' or 'thistle tube' shaped pulp chambers.
	Reginal odontoplysia	Ghost like appearance of teeth, large pulp chambers.
	Enamel pearl	
	Talons cusp	
	Turner's hypoplasia	Involved region appears as an ill-defined rl area.
	Congenital syphillis	
4.	Acquired Pathological Conditions (Figs 18.4A to C) (periapical/OPG)	
	Attrition	Change in outline of tooth structure, reduction in the size of the pulp chamber.
	Abrasion	rl defect at the cervical level of the tooth.
	Tooth brush injury	
	Dental floss injury of cervical areas.	Narrow semilunar rl in the inter proximal surfaces
	Erosion	rl defects on the crown.

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Fig. 18.3A: Anodontia

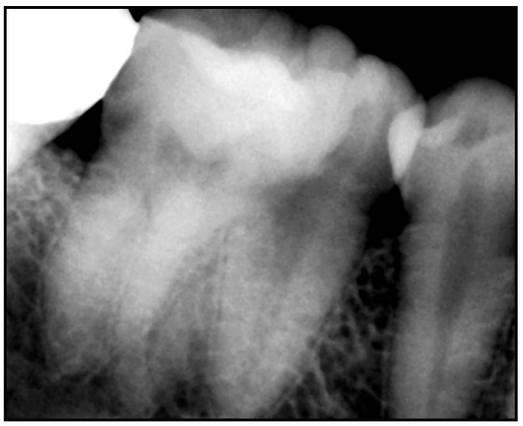

Fig. 18.3B: Fusion of 45, 46

Fig. 18.3C: OPG showing paramolars

Fig. 18.3D: Turner's tooth with periapical pathology

Fig. 18.3E: Mesiodens and impacted supernumerary tooth

Fig. 18.3F: Talon cusp on lateral incisor

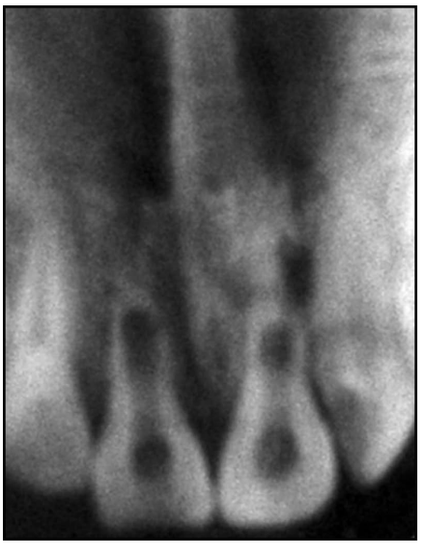

Fig. 18.4A: Internal root resorption

Fig. 18.4B: External root resorption

Fig. 18.4C: An ovoid pulp stone in maxillary lateral incisor

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	Resorption	rl round, oval or elongated lesions within the tooth.
	> internal	Blunting of the apex, with normal bone and lamina dura.
	> external	Lateral resorption, appear irregular and may involve one side more than the other.
	Secondary dentin	Reduction in the size of the pulp chamber
	Pulp stones	ro well-defined single or multiple structures in the pulpal chamber.
	Pulpal sclerosis	Ill-defined collection of fine ro in the pulp chamber.
	Hypercementosis	An excessive build up of cementum around all or part of the root.
5.	Inflammatory Lesions of the Jaws (Figs 18.5A to F)	
	Periapical inflammatory lesion	
	Acute	
	> acute apical periodontitis	– Widening of the PDL space.
	> acute apical abscess	– Thickened PDL space.
	> acute dentoalveolar abscess	– No radiographic changes except for thickening of PDL space, sometimes diffuse rl may be seen.
	Chronic	
	> chronic apical periodontitis	– Widened PDL space, with a band of ro sclerotic trabeculae.
	> periapical granuloma	– rl lesion, less than 1.5 cm in diameter, and well-defined.
	> periapical cyst	– rl lesion, more than 1.5 cm in diameter, with a sclerotic border.
	> condensing (sclerotic) osteitis	– Diffuse ro lesion of variable size and extent
	> osteosclerosis	– Exceptionally dense bone, may appear single or multiple with a round or irregular, well defined to an indistinct border.
	Osteomyelitis	
	i. Acute	– Fuzzy or blurred appearance of the trabeculae, with small rl areas.
	ii. Acute subperiosteal (occlusal)	– Erosion of cortex, moth eaten appearance. Evidence of new subperiosteal bone formation usually beyond the area of necrosis, particularly along the lower border of the mandible.
	iii. Chronic suppurative (OPG/lat.obl)	– Moth eaten appearance, sequestra is seen. Sclerosis of surrounding bone. Involucrum formation.

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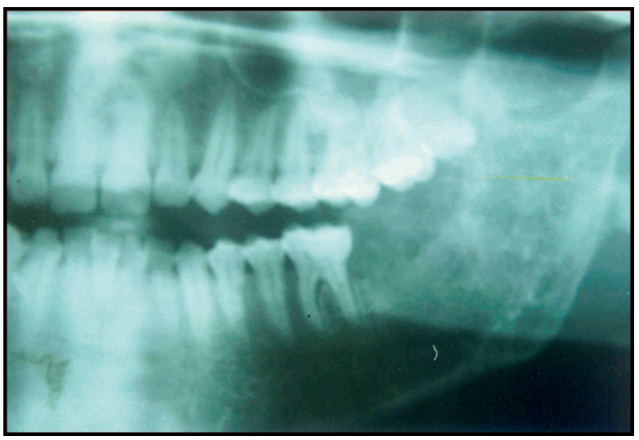

Fig. 18.5A: Condensing osteitis

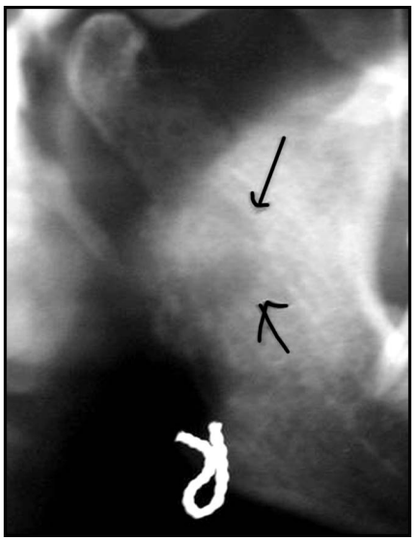

Fig. 18.5B: OPG showing ill-defined radiolucency, moth eaten appearance, osteomyelitis

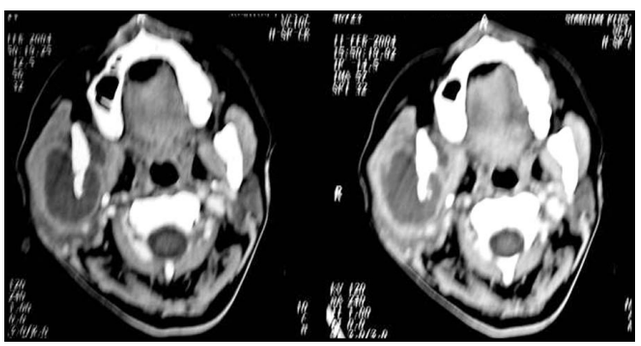

Fig. 18.5C: Axial CT showing hypodense peripherally enhancing lesion with erosion of bone (Ref. Fig. No. 18.5B)

Fig. 18.5D: Occlusal view showing condensing osteitis, as a well defined solitary, spherical diffuse radiopacity

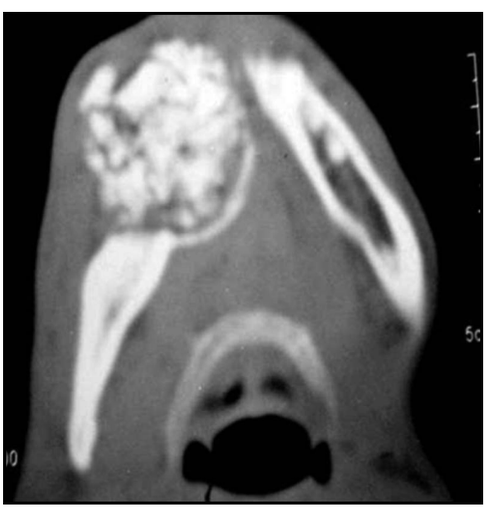

Fig. 18.5E: Axial CT of the lesion in Fig. 18.5D, showing an expansile lesion with heterogenous radiopacity

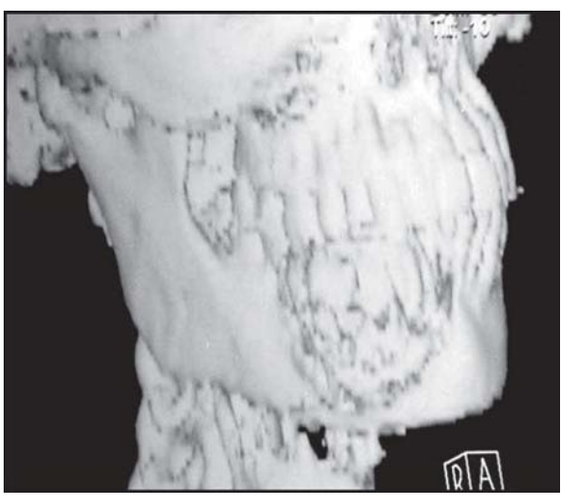

Fig. 18.5F: Shows 3DCT of the same lesion seen in Figs 18.5D and E showing perforation of the cortex

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	iv. Diffuse sclerosing (OPG/lat.obl)	– Ill-defined osteolytic lesions with osteosclerotic zones, which progressively become more osteosclerotic. *D/D:* – *eosinophillic granuloma* – *malignancy,* – *paget's disease* Other Diagnostic Aids– *Scintigraphic examination*
	v. Chronic subperiosteal (OPG/lat.obl)	– Shortening of the roots, moth eaten appearance, cortical sequestration.
	vi. Garre's osteomyelitis (occlusal)	– Onion skin appearance *D/D:* – *Ewing's sarcoma* – *Caffe's disease*
	> osteoradionecrosis	– rl and ro lesions with sequestra. Ragged, patchy 'moth eaten' appearance
	Pericoronal infections > pericoronitis > folliculitis (periapical)	– Defect in bone
6.	Cysts of the Jaws (Figs 18.6A to J)	– Well defined, unilocular or multilocular rl with or without cortication. – Has a definite shape; round, oval, pear shaped, etc. – Causes expansion of the overlying bone. – May lead to displacement or distortion of adjacent vital structures, e.g. teeth, inferior alveolar canal, etc. – Internal calcifications are sometimes seen.
	Odontogenic cysts	– Associated with the tooth forming apparatus. – Attached or in relation with a tooth or in place of a tooth. – May cause external root resorption or displacement of the tooth.
	> radicular cyst	– Well defined unilocular rl at the periphery of non vital teeth with a distinct sclerotic margin, continuous with lamina dura.
	> dentigerous cyst	– Unilocular cystic cavity with a well defined border. – Associated with the crown of an unerrupted tooth. – Adjacent teeth may be displaced – Buccal or medial expansion, may be extensive, with a large cyst causing facial asymmetry and displacement of the antrum.
	> residual cyst	– Round to oval rl, with a ro margin in relation to an empty socket.
	> odontogenic keratocyst	– Unilocular or multilocular, hazy rl due to the keratin filled lumen, with a thin sclerotic border, which may be smooth or scalloped adjacent teeth may be distally displaced and well defined. Expansion and perforation of cortical plate is rare.
	> basal cell nevus syndrome	– Bifid ribs, multiple jaw cysts; usually unilocular odontogenic keratocysts, in the mandible, (multiple nevoid basal cell carcinoma with occasional malignant transformation.) with ro focii.
	> primordial cyst	– rl lesion with well defined hyperostotic border with no involvement of unerupted teeth.
	> lateral periodontal cyst	– Well defined, round or oval rl with hyperostotic margins, usually gingival cyst, less than 1cm in diameter.
	Non odontogenic cysts	– May be fissural, developmental or traumatic. – Located along lines of fusion, embryonic process or at the site of trauma. – May cause divergence of roots with an intact lamina dura.
	> globulomaxillary cyst	– Well defined unilocular pear shaped rl, causing divergence of upper canine and lateral incisor (displaced teeth are vital).
	> median mandibular cyst	– Circular, well defined, unilocular rl with sclerotic border in the symphyseal region.
	> nasopalatine cyst	– Well defined heart shaped rl between the upper centrals, with a unisclerotic rim. There may be loss of definition of the lateral wall of the incisive canal.
	> median palatine cyst (occlusal)	– Well defined rl. behind the incisive canal in the premolar-molar area soft tissue cyst not visible on the radiograph
	> naso alveolar cyst	– Visible on injection of contrast media.
	> dermoid cyst	– rl with occasional ro images with characxteristic shapes and densities.
	> post operative maxillary cyst	– Unilocular or multilocular rl, on the inferior extension of the floor of the maxillary sinus. May cause pressure resorption of the maxillary alveolar bone.
	> static bone cavity	– ovoid rl with well defined dense ro borders found near the angle of the mandible adjacent to the inferior border of the mandible.

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Fig. 18.6A: Odontogenic keratocyst

Fig. 18.6B: OPG showing dentigerous cyst

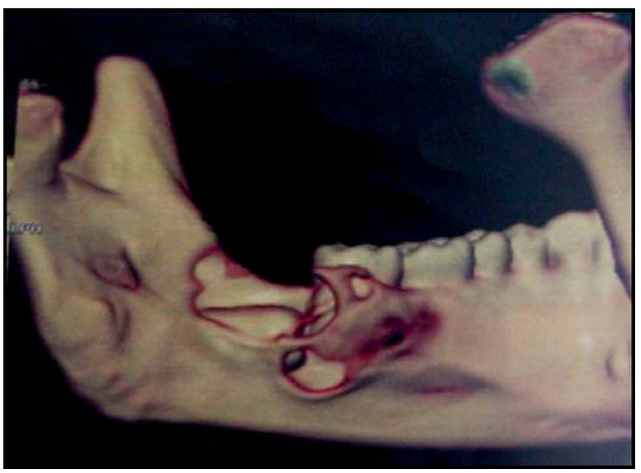

Fig. 18.6C: 3DCT showing dentigerous cyst (Ref. Fig. No. 18.6B)

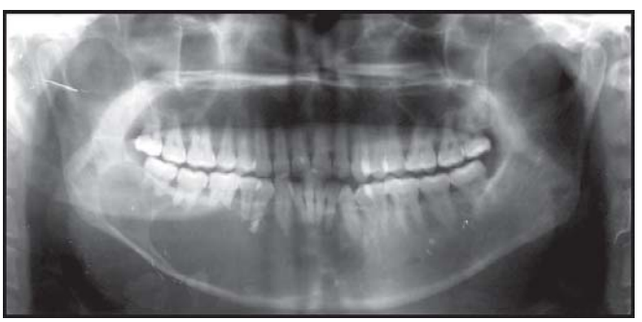

Fig. 18.6D: OPG showing unilocular radiolucency with sclerotic borders and slight root resorption-cyst

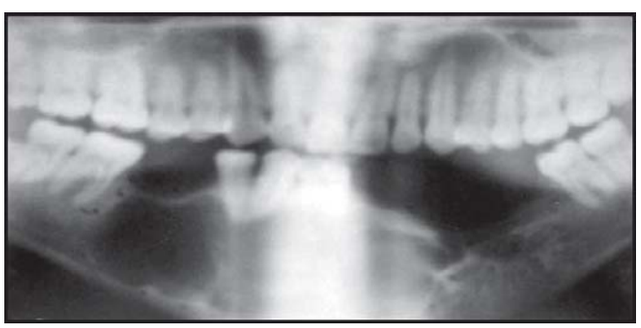

Fig. 18.6E: OPG showing a multilocular radiolucent lesion crossing the midline, encroaching the inferior alveolar canal

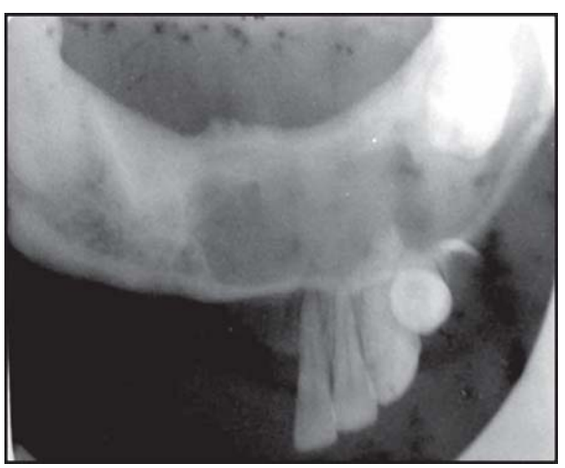

Fig. 18.6F: Occlusal view of the OKC seen in Fig. 18.6E

Fig. 18.6G: CT coronal section showing a well defined cyst, with thinned out cortex and impacted tooth

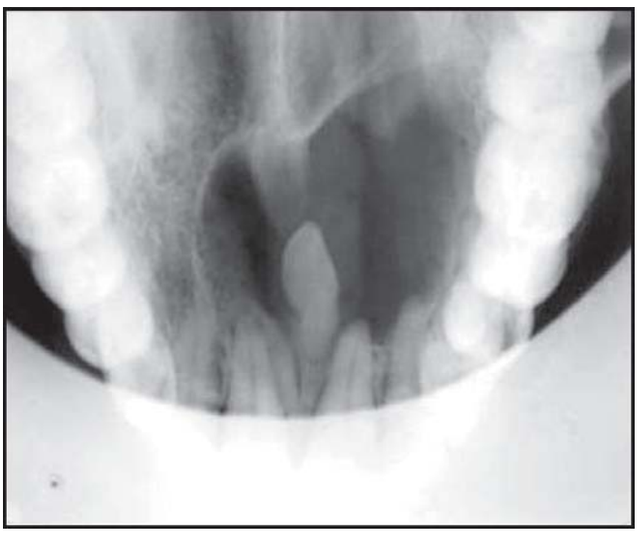

Fig. 18.6H: Dentegerous cyst associated with an inverted mesiodens on an occlusal radiograph

Fig. 18.6I: Globulomaxillary cyst

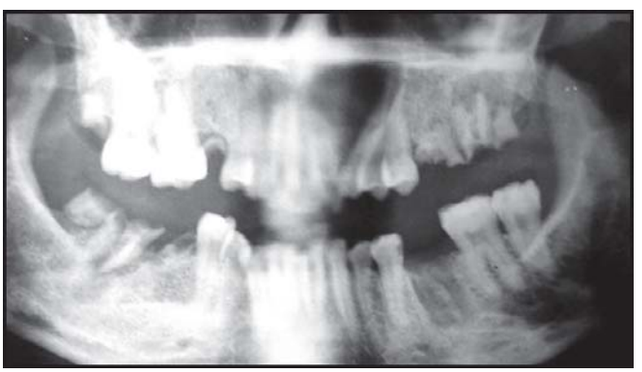

Fig. 18.6J: OPG showing globulomaxillary cyst

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
7.	Benign tumors of the jaw (Figs 18.7A to V)	– Specific anatomical regions, e.g. vascular and neural lesions arise in the mandibular canal, etc. – Borders are usually smooth, well defined, scalloped and sometimes corticated. – May have a capsule around it which appears as a rl band. – Internally it may be rl or ro depending on its contents – Curved septa may be seen. – Roots may be resorbed (external root resorption) sometimes they may be displaced . – Perforation of bone is rare, distortion of the bone by expansion may occur.

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	Hyperplasia	
	> exostoses torus palatinus (periapical/occlusal)	– Dense well defined ro shadow superimposed on the apex of maxillary molars.
	torus mandibularis periapical/occlusal	– Well defined ro shadow superimposed on the roots of mandibular molars. On the occlusal radiograph. They appear as ro knobbly protuberances.
	> endostosis	– ro mass with well defined irregular margins, no prominent cortical expansion noted.
	Odontogenic Tumors	
	Ectodermal	
	> ameloblastoma	have various appearances; – Unilocular cyst like appearance with a hyperostotic border. – Rl, with smooth curved margins, with coarse trabaculae arranged within to appear as a 'spider'. – Multilocular cyst like appearance with septa. – Cyst like cavity with borders are undulating arcs or made up of small arcs of small circles, suggesting more than one lesion. – Large cystic cavity with one or more daughter cysts. – Solid variety, honey comb appearance or soap bubble appearance. – Root resorption of adjacent teeth. – Buccolingual cortical expansion. – Occasional transformation to malignant form.
	> adenomatoid odontogenic tumor	– Well defined unilocular rl associated with an unerrupted tooth, distinctive sclerotic margin and multiple ro foci within the rl space. *D/D: - pindborgs tumor* Gorlin's cyst ameloblastoma
	> calcifying epithelial odontogenic tumor	– rl area surrounding the crown of an unerupted mature tooth.(pindborg's tumor) – rl which may be unilocular or multilocular cystic lesion with numerous scattered ro foci of varying sizes—'driven snow 'appearance.
	Mixed Tumors	
	> Odontoma i. Compound	– Multiple tooth like bodies within a rl rim, often associated with impacted tooth.
	ii. Complex	– Uniform ro calcific mass with irregular borders, surrounde by a rl band, often associated with an impacted tooth.
	> ameloblastic fibroma	– Unilocular or multilocular rl associated with an impacted tooth.
	Mesodermal	
	> odontogenic myxoma	– Multilocular soap bubble rl with a distinctive 'tennis racket' appearance.
	> benign cementoblastoma	– It has three appearances depending on the stage of development.Well defined ro attached to the root of a premolar or molar, with a rl halo. It has an expansile nature. Usually solitary, 1-8 cm in diameter, causing expansion of lingual and buccal plates.
	> dentinoma	– ro mass or several masses, usually associated with the crown of an unerrupted tooth, with a rl band.
	Non Odontogenic Tumors	
	Ectodermal	
	> Neurilemmoma	– Oval rl area, usually distal to mental foramen, it may cause root resorption and have a multilocular appearance with hyperostosis borders.
	> neuroma	– rl area in bone with well defined borders, in the mandible it is usually associated with the mandibular canal.
	Mixed Tumors	
	> Neurofibroma	– When associated with the inferior dental nerve, it has a fusiform rl appearance,with sharp, well defined hyperostosis borders.
	Mesodermal Tumors	
	> Osteoma	– Well defined ro mass.

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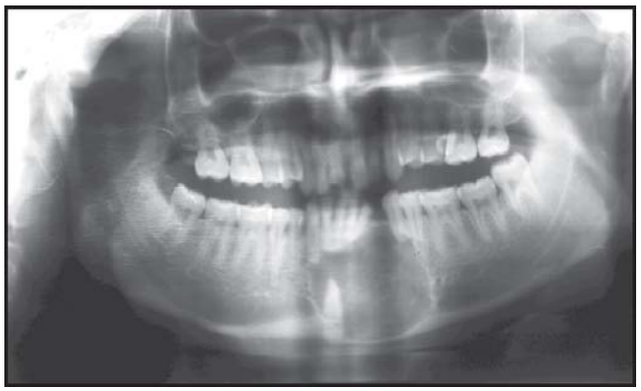

Fig. 18.7A: OPG showing AOT

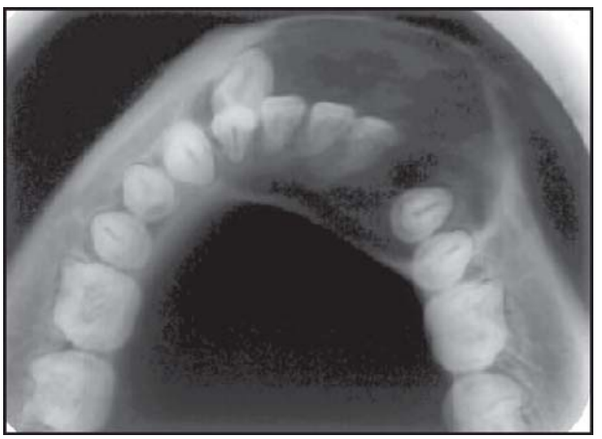

Fig. 18.7B: Occlusal radiograph showing AOT

Fig. 18.7C: Cementoma

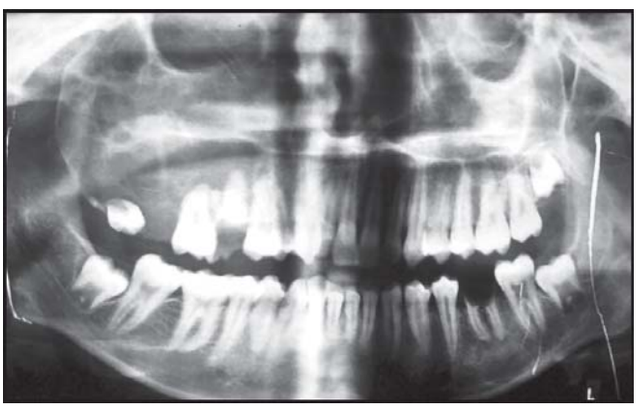

Fig. 18.7D: OPG showing central fibroma

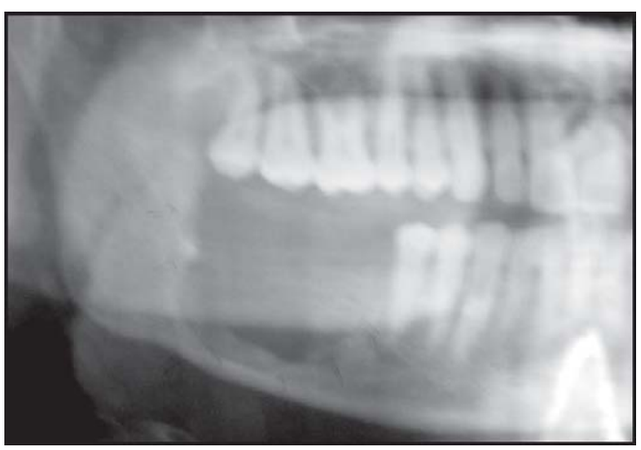

Fig. 18.7E: OPG showing central giant cell

Fig. 18.7F: OPG showing multilocular ameloblastoma

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S.No.	Pathology (Radiographic view recommended)	Radiographic appearance
	Gardner's Syndrome	– is a hereditary condition associated with multiple osteomas, cutaneous sebaceous cysts, subcutaneous fibromas and multiple polyposis of the small and large intestines.
	> central hemangioma	– Osteolytic defect with well defined borders. – Locules formed with enlarged trabecular spaces, the trabaculae may be coarse, dense and well defined, having a soap bubble or honey comb appearance, sun ray or sunburst appearance, cart wheel appearance. – Roots of the involved teeth are resorbed and phleboliths are not uncommon.
	> arteriovenous lesion	– May erode bony surface and cause well defined rl lesions in the bone. The central lesions may be multilocular.
	> chondroma	– Irregular rl image with borders which may be well defined or ragged. It may develop ro in the osteolytic region giving a mottled appearance.
	> osteoblastoma	– Varied appearance from rl to having varying degree of calcifications. The borders may be diffuse or show signs of cortication.
	> osteoid osteoma	– Small ovoid or round rl surrounded by sclerotic bone. It may have ro foci.

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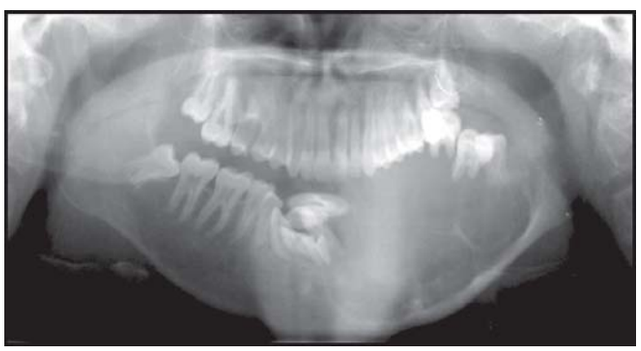

Fig. 18.7G: OPG showing neurofibroma

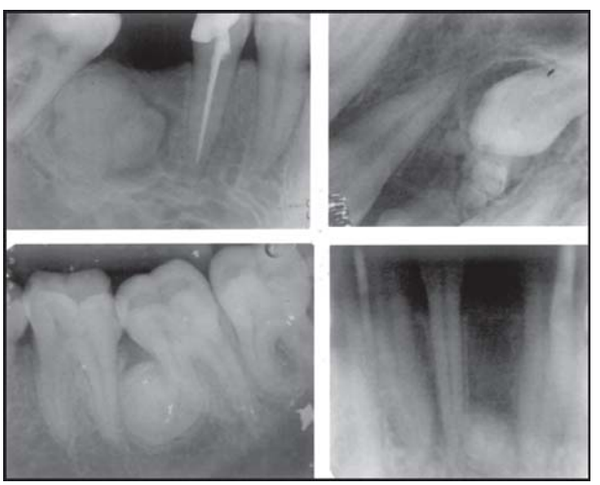

Fig. 18.7H: Odontoma

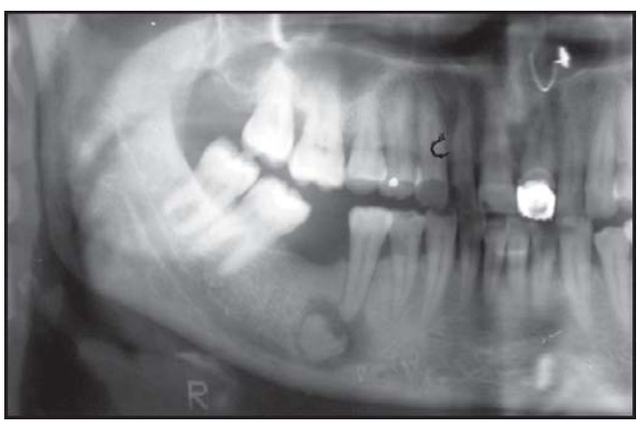

Fig. 18.7I: Odontoma

Fig. 18.7J: IOPA showing AOT

Fig. 18.7K: Axial CT showing AOT with tumor mass displacing the nasal cavity and maxillary sinus

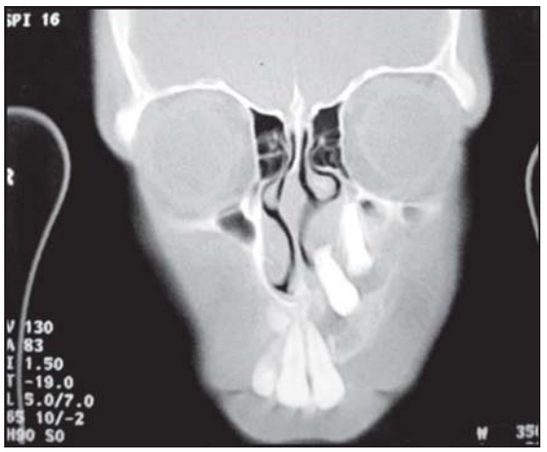

Fig. 18.7L: Coronal CT showing AOT with unerupted teeth with scattered radiopaque foci causing displacement of nasal septum and maxillary sinus

Fig. 18.7M: OPG showing multilocular lesion with soap bubble appearance and root resorption

Fig. 18.7N: 3DCT of ameloblastoma with destruction of the buccal and lingual cortical plates

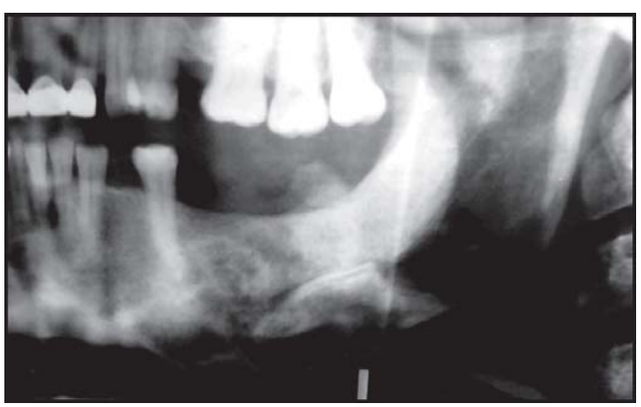

Fig. 18.7O: Ossifying fibroma, OPG shows a solitary well defined corticated radiolucency

Fig. 18.7P: IOPA showing central giant cell granuloma, radiolucency with cortication and resorption

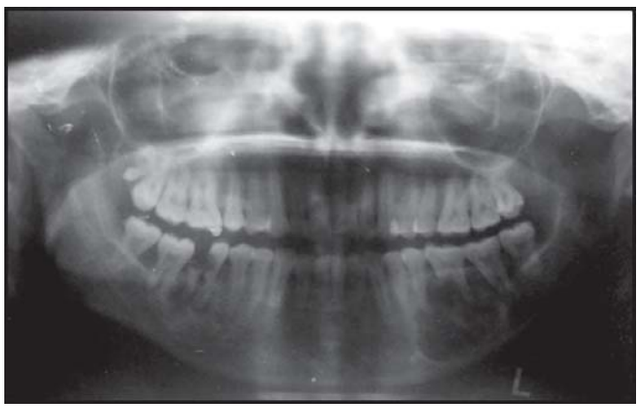

Fig. 18.7Q: OPG showing a solitary, expansile, multilocular lesion, which is causing root resorption

Fig. 18.7R: Central fibroma seen on occlusal view, as a multilocular radiolucency with balloning of cortex

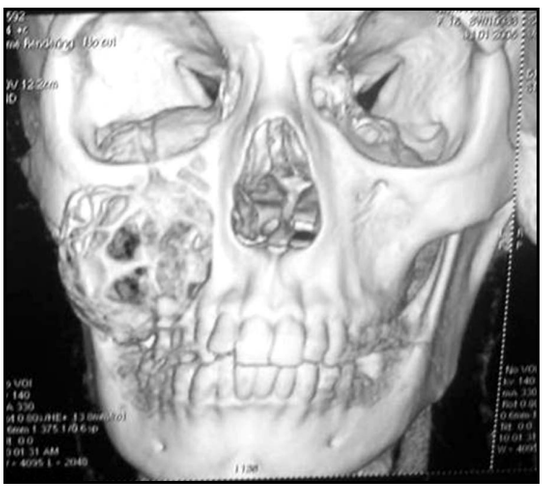

Fig. 18.7S: Central fibroma (Ref. Fig. 18.7R) 3DCT showing multilocular lesion with well defined septae

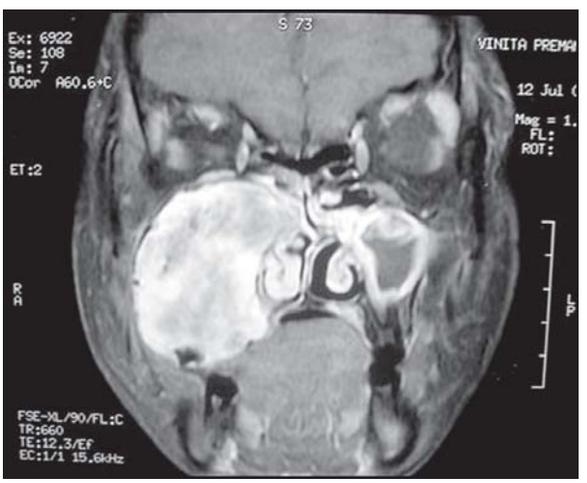

Fig. 18.7T: MRI- Scan T2 coronal section showing central fibroma, (Ref. Fig. 18.7R) lesion seen as heterogenous hyperintensity

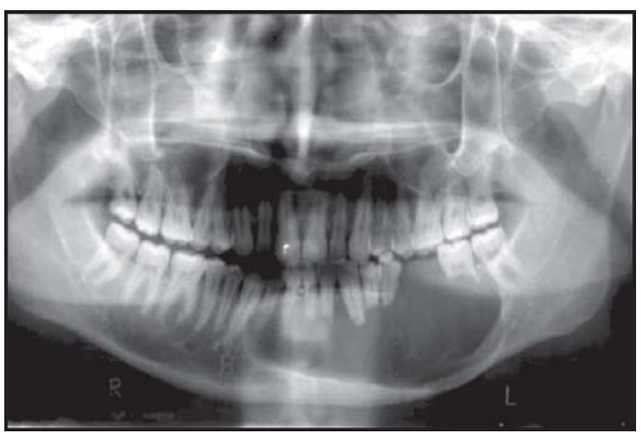

Fig. 18.7U: Unilocular ameloblastoma

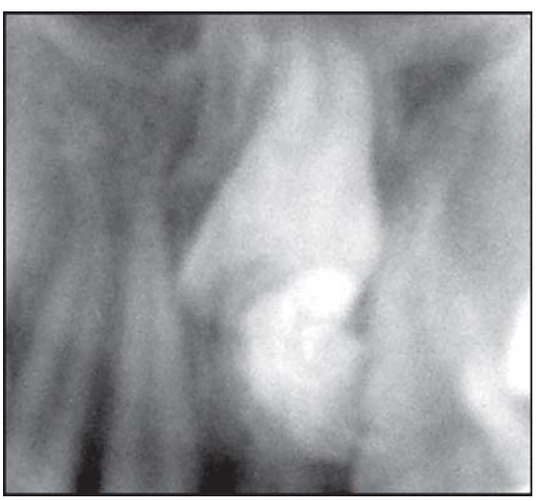

Fig. 18.7V: Compound composite odontoma

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
8.	Malignant tumors of the jaws (Figs 18.8A to H)	– Ill-defined borders, with lack of cortication and absence of encapsulation. – Infiltrative border with finger like extensions. – Multiple radiolucencies. – Floating teeth appearance. – Metastatic tumors may induce bone formation.
	> carcinoma	– Destructive infiltrative lesion with ill-defined margins, the border may have a zone of diffuse radio density. There are various appearances: – Permeated-bony destruction with ill-defined margins. – Moth eaten type- rarefactions with remnants of small bony fragments. – Pressure type- cortical bone destruction and pathological fractures. – Rarefactions without osteosclerotic borders may also be seen. – The involved teeth have a 'floating teeth appearance' – When root resorption occurs, it is more on the lateral surface.
	> metastatic carcinoma	– Ill defined rl destructive lesions, which may be single or multiple and vary in size. Or they have an osteolytic appearance with some bone formation
	> malignant tumors of salivary glands	– The lesion may invade bone showing erosion. Mucoepidermoid tumors appear multilocular rl lesions with scalloped well defined borders.
	> sarcoma	
	Osteosarcoma	Three types of appearance depending on the stage of the disease; – Osteolytic rl appearance. – ro osteoblastic appearance. – Mixed rl image with ro foci. – Unicenteric with ill-defined borders. – Subperiosteal bone formation- 'sun ray', 'onion peel' appearance and 'codman's triangle.
	Chondrosarcoma	– Lytic lesion with poorly defined borders, or mixed lesion having a soap bubble appearance.
	Fibrosarcoma	– Destructive osteolytic lesion with displacement or or erosion of teeth and smooth pressure resorption of the underlying bone.
	Ewing's sarcoma	– Unilocular or multilocular, destructive rl lesion with sclerotic margins. It may stimulate the periosteum to give an 'onion peel' or 'sun ray' appearance.
	> hematological neoplasms	
	Leukemia	– Osteoporosis, destruction of the crest of the alveolar bone 'flame shaped' appearance, loss of lamina dura and loosening of the teeth. Multiple ill-defined rl lesions resembling periapical inflammatory disease, and may also stimulate new bone formation-'onion peel' appearance. – Skull may show patches of radiolucency.
	> immunologic neoplasms	
	Malignant lymphoma	– Ill defined lytic lesions in the posterior aspect of the maxilla and mandible.
	Burkitt's lymphoma	– Loss of lamina dura, expanding lesion with large multilocular rl, moth eaten rl with poorly defined margins. At the periphery it stimulates new bone formation- 'sun ray' appearance. The teeth may be resorbed or shed.
	Multiple myeloma (true lateral, PA Skull)	– multiple, small well defined radiolucencies, without a sclerotic border giving a punched out appearance. Borders of these lesions may display a thin sclerotic rim. Usually occur bilateral. Keenly observed on the skull.

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Fig. 18.8A: Axial CT showing mass arising from the base of the tongue- Carcinoma of the tongue

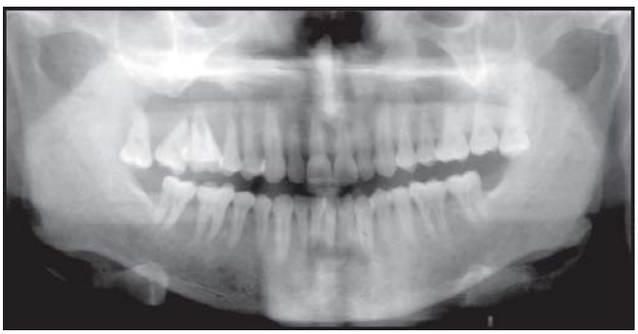

Fig. 18.8B: Carcinoma of right Maxilla, OPG shows an ill-defined radiolucency with permeating borders

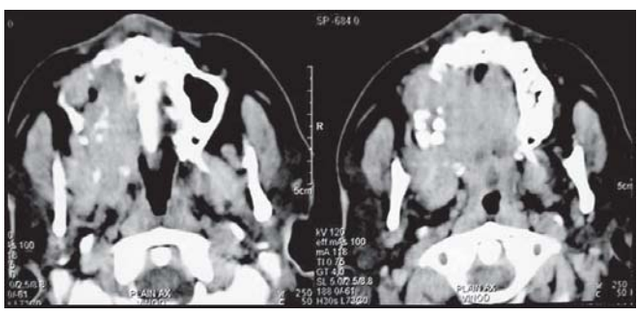

Fig. 18.8C: Axial CT show an isodense to hypo dense heterogenous enhancing growth with destruction (Ref. Fig. 18.8B)

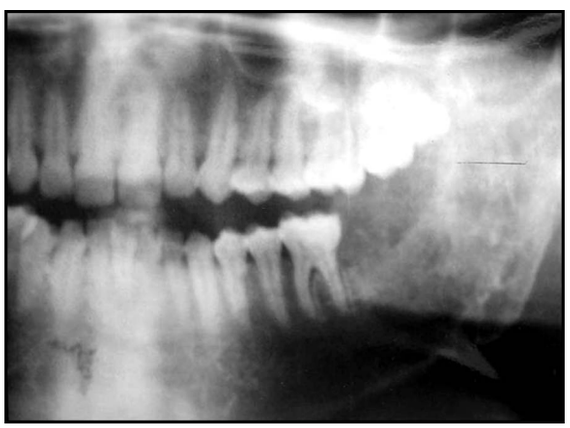

Fig. 18.8D: Osteosarcoma seen on the OPG as an ill-defined radiolucency with interspersed radiopacity

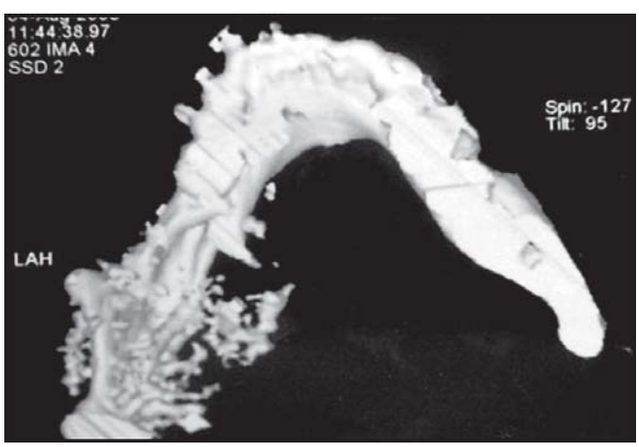

Fig. 18.8E: 3DCT of the Osteosarcoma seen in Fig. 18.8D showing 6.5 × 6 × 6 cm lesion with osteolysis

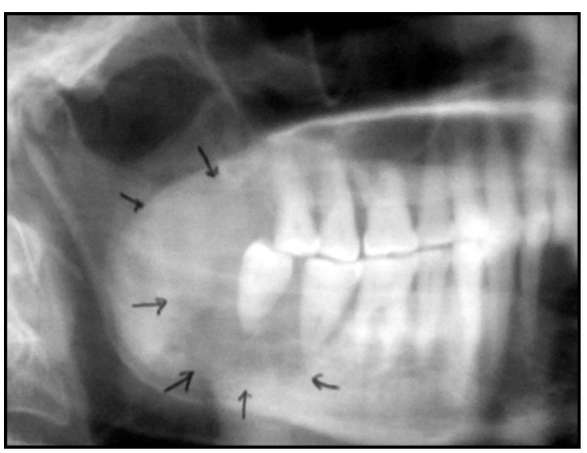

Fig. 18.8F: OPG shows ill-defined radiolucency near angle of mandible with extensive destruction

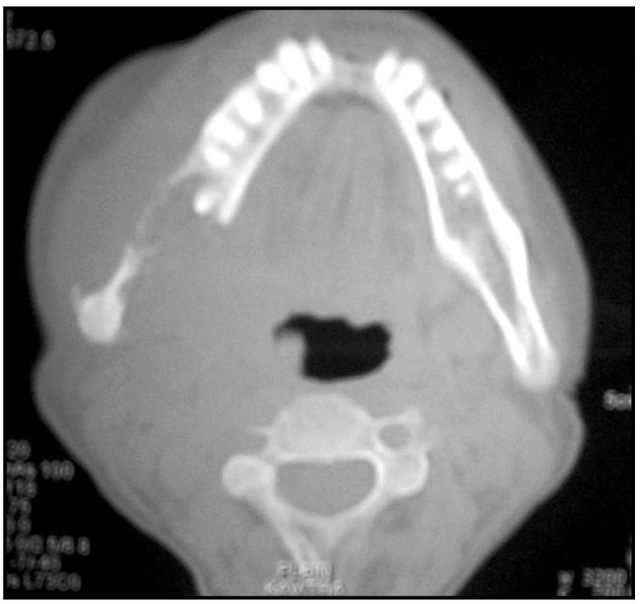

Fig. 18.8G: Shows axial CT picture of Fig. 18.8F with destruction of the ramus and posterior body of mandible

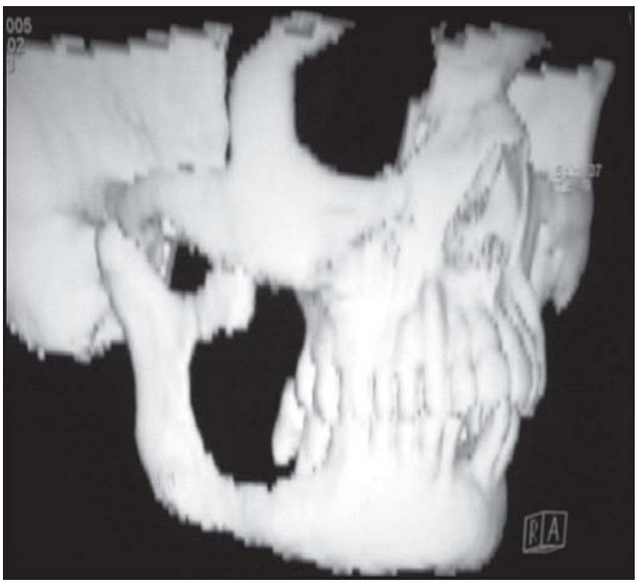

Fig. 18.8H: 3DCT of Fig. 18.8F showing gross destruction of the ramus and body of mandible

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
9.	Diseases of Bone manifested in the Jaws (Figs 18.9A to H)	
	Fibro-osseous Lesions	
	> fibrous dysplasia	– Appearance is non uniform depending on the content ratio of fibrous ossifying fibroma versus osseous formation; appearance varies with the degree of maturation and occurrence site. – Cyst like rl, when the composition is fibrous in nature. – 'Ground glass' or 'orange peel' or 'finger print' stippled type ro appearance when the composition is mainly osseous in nature. – Poor definition of the edge of the lesion which merges imperceptibly with the surrounding bone. – May have a granular appearance, with irregular rl and ro. – Bone is thickened, lamina dura is lost, cortex is thinned, thinning of the peridontal ligament shadow, teeth may be moved bodily. – Enlargement of the affected bone and encroachment on the antral space – Displacement of associated teeth – Bony expansion, occasional malignant transformation.
	> periapical cemental dysplasia	Has three distinct stages: Stage I- rl early stage, with small foci of calcific masses. Stage II- mixed intermediate stage, rl with ro foci. Stage III-ro stage, with substantial opacification of the lesion, resulting in a well defined solitary or multiple ro homogenous mass, with a thin rl margin. – Usually less than 1cm in diameter. – Lamina dura of adjacent teeth is usually discontinuous. – No root resorption or displacement. – Usually lower incisors affected.
	> ossifying fibroma	Has three distinct stages: Stage I- rl early stage, with small foci of calcific masses. Stage II- mixed intermediate stage, rl with ro foci.

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Fig. 18.9A: Florid osseous dysplasia

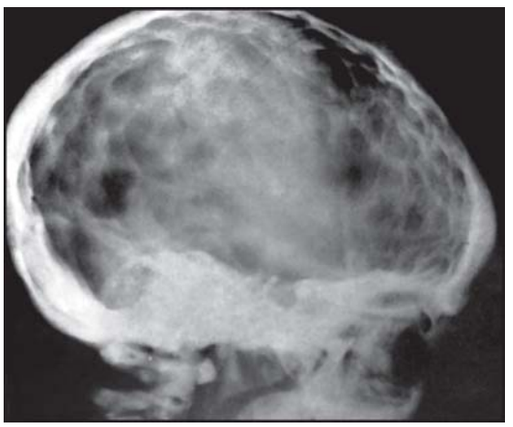

Fig. 18.9B: Copper beaten appearance in osteosclerosis

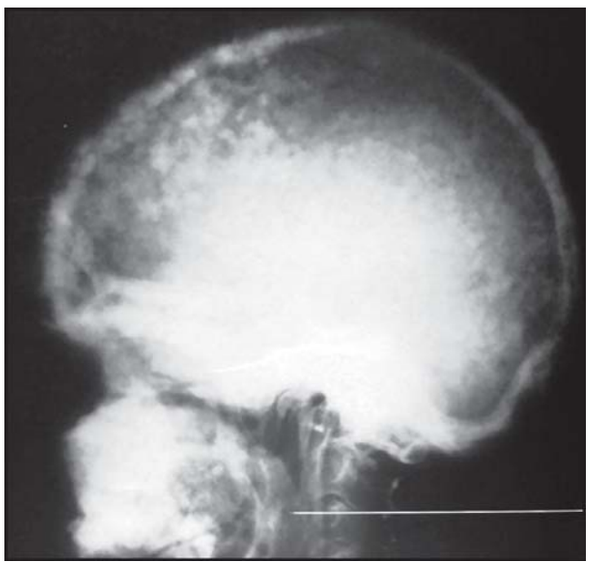

Fig. 18.9C: Cotton wool appearance of Paget's disease

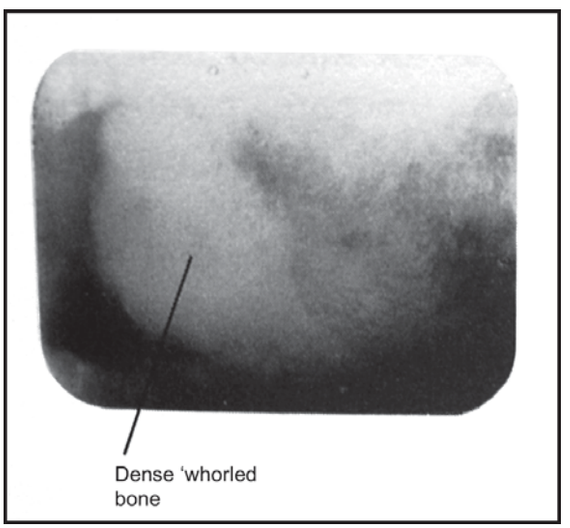

Fig. 18.9D: Fibrous dysplasia

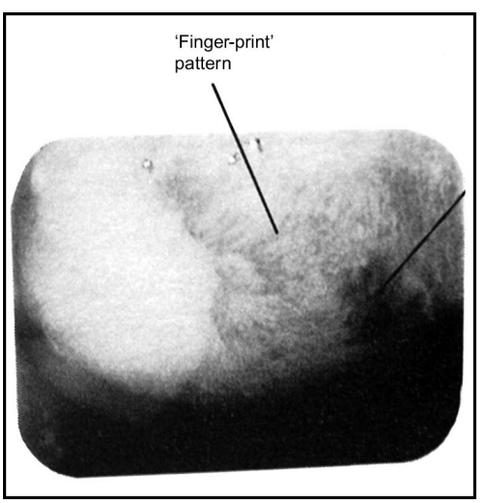

Fig. 18.9E: Fibrous dysplasia

Fig. 18.9F: Fibrous dysplasia, occlusal view showing orange peel appearance

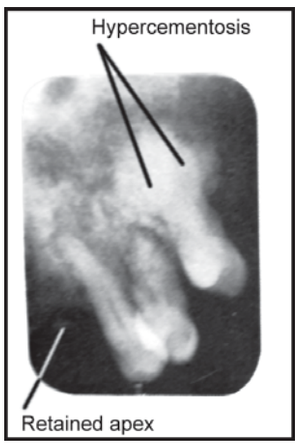

Fig. 18.9G: IOPA radiograph showing hypercementosis-Pagets disease

Fig. 18.9H: Loss of lamina dura-Paget's disease

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
		Stage III-ro stage, with substantial opacification of the lesion, resulting in a well defined solitary or multiple ro homogenous mass, with a thin rl margin. – May be multilocular, and may expand vigorously if untreated. – Root resorption or displacement is common. – Found commonly in premolar- molar region.
	> florrid osseous dysplasia	– Is a reactive type of fibro-oseous lesion originating from the periodontium. It has three distinct stages; Stage I- rl early stage, with small foci of calcific masses. Stage II- mixed intermediate stage, rl with ro foci. Stage III-ro stage, with substantial opacification of the lesion, resulting in ro masses that have a lobular or lumpy shape and a fluffy soft ro character akin to 'cotton wool' appearance. It has indistinct margins due to its infiltrative nature.
	> cherubism	– It is characterize by multiplicity of lesions in both the jaws. It causes buccal or labial expansion, with no facial asymmetry – No root resorption or displacement. – Found throughout the jaw affecting the alveolar process. – Multilocular cyst like rl, with relatively well defined margin with a sclerotic rim. Produces bilateral swelling due to expansion of the cortical plates. – Displacement of numerous tooth buds and dental follicles. – Floating teeth appearance.
	Reactive Lesions	
	> central giant cell granuloma	– Unilocular or multilocular well defined rl in lower molar region, having 'soap bubble' appearance. The rl has fine internal septa having a 'wispy' appearance.
	> aneurysmal bone cyst	– Unilocular or multilocular radiolucency, with bony expansion. – It may have a soap bubble appearance.
	Other Lesions	
	> Paget's Disease (osteitis deformans)	– An early rl resorptive stage.A granular or 'ground glass' appearance of the maxilla and mandible (early stage) – A dense ro appositional late stage.- 'cotton wool' appearance (late stage) – Altered internal bone pattern is observed, where the trabeculae are reduced in number and run linearly in the direction of the length of the bone.

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
		– Enlargement of the affected bone
		– Early pagetoid lesions may resorb roots, hypercementosis, loss of lamina dura with widened periodontal ligament space, separation and displacement of teeth is commonly observed.
		– In the skull lytic lesions may be seen as discrete rl areas called 'osteoporosis circumsepta'.
		– Obliteration of the sinus may occur.
	> osteopetrosis	– Radiographic picture in truly sine qua non of the disease.
	(marble bone disease)	– All bones show greatly increased density, osteosclerotic changes which is bilaterally symmetrical.
	(Albers-Schonberg disease)	– Uniformly dense radiopaque skull vault
		– Loss of normal skull markings and structure
		– Gross thickening and increased opacity of the cranial base with narrowing of the foramina
		– Thickening of the trabeculae and gradual loss of bone marrow space, producing an overall increase in bone density.
		– Bones are prone to pathological fractures.
		– Dental defects include delayed eruption, early loss of teeth, missing teeth, malformed roots and crowns and teeth are poorly calcified and prone to caries.
		– Thickening of the lamina dura in the early stages.
		– Osteomyelitis of the jaws, common.
	> infantile cortical hyperostosis	– Thickening of the inferior cortex, giving a laminated appearance.
	> traumatic bone cyst	– Usually seen above the mandibular canal, a rl ranging from well defined to somewhat ill-defined margins. Hyperostotic border, with a pathognomonic scalloping pattern inter digitating along the roots with or without displacement of teeth or root resorption.
10 .	Systemic Diseases manifested in the Jaws (Figs 18.10A to H)	
	Endocrinal	
	> hyperparathyroidism	Demineralization of the skeleton, ostetitis fibrosa generalisate, i.e. localized destruction of bone showing rl areas, 'Brown's tumor, these are cyst like also called osteitis fibrosa cystica., following treatment these lesions disappear.
		– Evidence in the skull vault of osteopenia producing a fine overall stippled pattern to the bone- 'pepper pot' skull.
		– Osteopenia, producing fine trabecular pattern- 'ground glass'.
		– Pathological calcifications in kidneys and joints.
		– Erosion of bone from subperiosteal surfaces.
		– Demineralization of the inferior border and the mandibular canal.
		– Cortical outline of the maxillary sinus is thinned.
		– Generalized loss of lamina dura and osteoporosis with abortive attempts at repair.
	> hypoparathyroidism (skull radiograph)	– Enamel hypoplasia, delayed eruption, external root resorption, dilacerations, abnormal calcification and enlarged pulp chambers.
		– Ectopic calcifications.
		– Calcification of the basal ganglia.
	> hyperpituitarism	– Gigantism/ acromegaly.
		– Ballooning of the sella turica, enlargement of the paranasal sinuses, increased prominence of the supraorbital ridge, diffuse thickening of the anterior table of the skull.
		– Roots of the posterior teeth are enlarged due to secondary cemental hyperplasia.
		– Lengthening of the condylar process causing Class III skeletal relationship.
		– New bone is laid at the crests of the alveolus resulting in an anterior open bite.
	> hypopituitarism	– Dwarfism / Simmonds disease.
		– Delayed eruption and shedding of teeth, absence of third molars, marked alveolar resorption is seen.
	> hyperthyroidism	– Accelerated shedding and eruption of teeth.
		– In adults there is generalized decrease in bone density or atrophy of alveolar bone in edentulous areas.

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S.No.	Pathology (Radiographic view recommended)	Radiographic appearance
	> hypothyroidism	– Cretinism/myxedema delayed fusion of bones, delayed ossification of the base of the skull and partial pneumatization of the Para nasal sinuses. – Eruption is delayed and deciduous teeth are over retained. – The skull radiograph shows wormian bones, there is generalized thinning of the lamina dura and roots appear shortened.
	> diabetes mellitus	– Radiographically no distinct changes are seen, a slight discontinuity or blurring of the cortex of the alveolar crest, to wide destruction of the lamina dura and inter dental bone may be seen.
	> cushing syndrome	– Generalized osteoporosis, osseous demineralization with pathological fractures. – The skull shows diffuse thinning and a mottled appearance. – Generalized loss of lamina dura is seen.
	> albright's syndrome	– Polyostotic fibrous dysplasia – Café au lait spots – Endocrinal disturbances;precocious puberty, hyperparathyroidism, hyperthyroidism, cushing's syndrome, acromegaly – Most exclusively seen in females
	Others	
	> histocytosis X, letter-sieve disease	– Destruction of bone starting from the alveolus, 'saucer shaped' lesion with a well defined outline, which progress with the ultimate loss of teeth. – The skull may show multiple area of rl with irregular borders.
	Hand-schuller-christian disease	– Alveolus bone destruction similar to that of LSD. – Skull shows areas of rl with a smoother outline. This is a component of a triad- the other two being; diabetes insipidus and exopthalmus.
	eosinophillic granuloma	– The skull shows solitary or multiple, osteolytic lesions, having a discrete border- 'punched out' appearance. -There is destruction of the alveolar process giving a 'Floating teeth' appearance.
	> osteoporosis	– Reduced density and thickness of the inferior mandibular cortex, reduction in the overall quantity of trabeculae.
	> Hurler's syndrome	– Teeth are small and spaced – Crypts of developing teeth are separated from the enamel – Dentigerous cysts – Chin is retruded, mandible is wide across the angles – Condyles are flattened, sigmoid notch is deep and wedge shaped – Skull is dolichocephalic and there may be frontal prominence.
	> rickets	– Widening and fraying of the epiphyses of the long bones, – Green stick fractures, – Thinning of the corticated structure of the jaw, e.g. walls of the mandibular canal, – Loss of lamina dura, thinning of the follicular walls of developing teeth. – Trabeculae become reduced in number. – Hypoplasia of developing dental enamel, unerupted teeth and retarded eruption.
	> osteomalacia	– Patients have thin bones and prone to pseudo fractures. -Generalized rl appearance of the jaws, coarse trabeculae, thinned lamina dura
	> hypophosphotasia	– Skull sutures close early leading to bulging and gyral marking on the internal surface of the skull, 'beaten copper' appearance. – The jaws show generalized rl . with thinning of cortical bone and lamina dura. – Teeth show deficient enamel thickness and large pulp chambers and root canals.
	> renal osteodystrophy	– Generalized loss of bone density and thinning of the bony cortices. – Loss of lamina dura. – Other bones may show sclerosis.
	> hypophosphatemia	– Thinning of jaw cortical structures,

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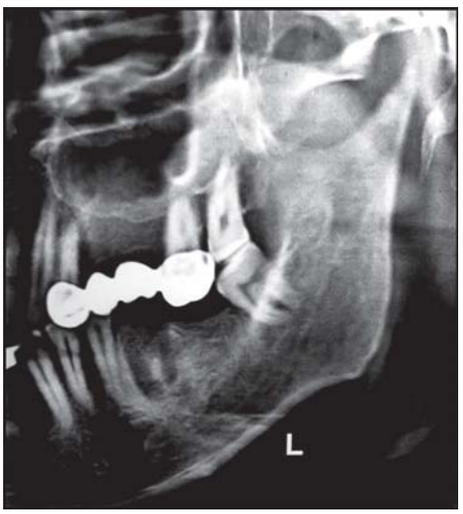

Fig. 18.10A: OPG showing resorption of the condylar head due to tuberculosis

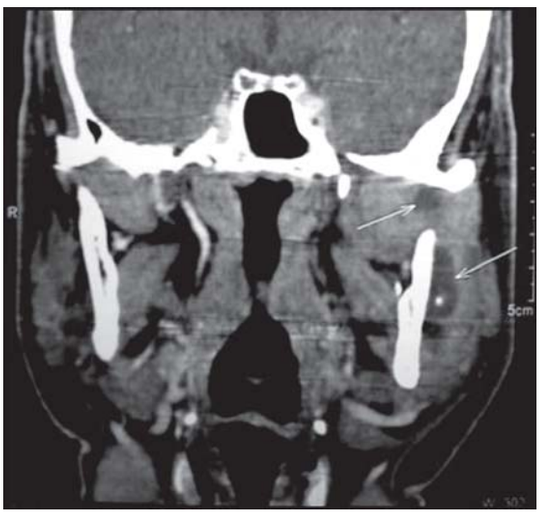

Fig. 18.10B: Coronal CT showing abscess formation in left TMJ with infectious destruction (TB) (Ref. Fig. 18.10A)

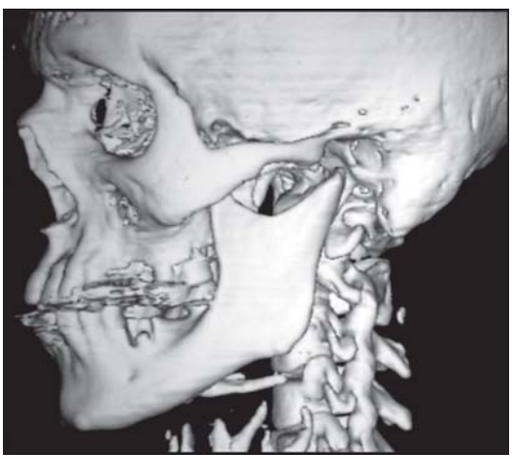

Fig. 18.10C: 3DCT showing resorbed condyle (TB) (Ref. Fig. 18.10A)

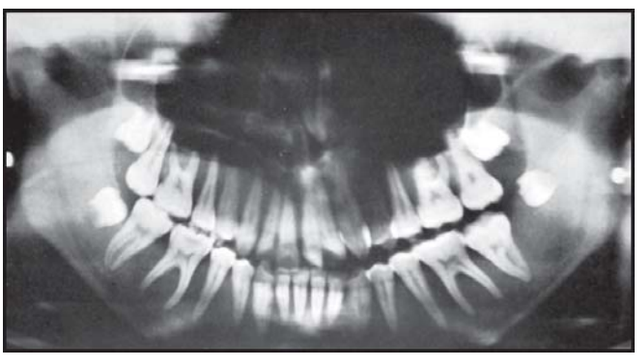

Fig. 18.10D: Generalized loss of lamina dura in hyperparathyroidism

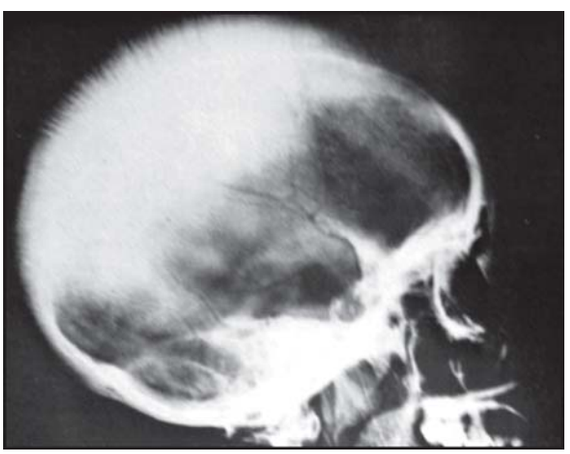

Fig. 18.10E: Hair end on appearance in sickle cell anaemia

Fig. 18.10F: Hair end on appearance on PA view –Sickle cell anaemia

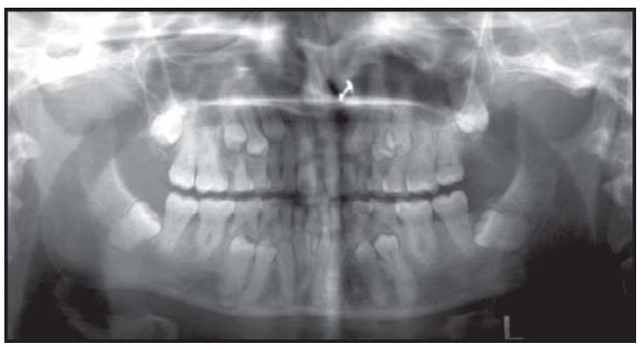

Fig. 18.10G: Multiple impacted teeth and retained deciduous teeth in hypothyroidism

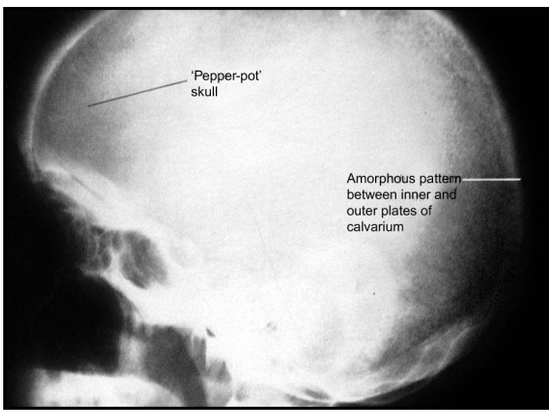

Fig. 18.10H: Pepper pot appearance of hyperparathyroidism

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	(Vit. D. resistant rickets)	– Teeth may be poorly formed with thin enamel caps and enlarged pulp chambers and root canals. – High incidence of periapical and periodontal abscesses.
	> progressive systemic sclerosis	– Widening of the periodontal ligament space with an intact lamina dura. – Presence of mandibular erosions near the angle, which is bilateral and fairly symmetrical. – The coronoid process may also be resorbed or amputed.
	> prolonged steroid therapy	– Simulates cushing syndrome, generalized osteoporosis and loss of lamina dura.
	> sickle cell anemia	– Thickening of the frontal and parietal bones skull shows widening of the diploic space, thinning of the inner and outer tables. – 'Hair on end' appearance – Osteomyelitis may complicate the picture – Generalized osteoporosis of the mandible – Thinning of the cortical plates – An accentuated 'step ladder' pattern of the trabeculae enlargement of the maxillae, with protrusion and separation of the anterior teeth – Osteosclerotic area resulting from the infarcts
	> thalessemia (Cooley's anemia)	– Generalized rl of long bones with cortical thinning. – Pathological fractures. – In the skull there is thickening of the diploic space in the frontal region. – The skull has a granular appearance with a 'hair –on-end' appearance. – There is retarded puematization of the paranasal sinuses. – The jaws show generalized rl, lamina dura is thin, roots are short and 'spike shaped' and the premaxilla is often prominent. – The maxilla and mandible show large marrow spaces and paucity of trabeculae. – Cortex of the mandible is thinned especially at the angle. – Expansion may lead to encroachment on and subsequent obliteration of the maxillary antra.
11.	Temperomandibular Joint (Figs 18.11A to G)	
	> internal derangement (arthrography, CT, MRI)	– Not well visualized on the radiograph – Osseous change like, porosity, osteosclerosis, hypertrophy. – Osteophytes may be seen. – Pathophysiological remodelling and narrowing of the TMJ.
	> arthritis osteoarthritis rheumatoid arthritis	– More severe osseous changes of the condylar head flattening of the eminence. – Flattening of the condylar head, with erosions. The condylar outline becomes irregular resembling, 'sharpened pencil' or 'a mouth piece of a flute'.

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Fig. 18.11A: MRI showing anterior disc displacement with disc deformation

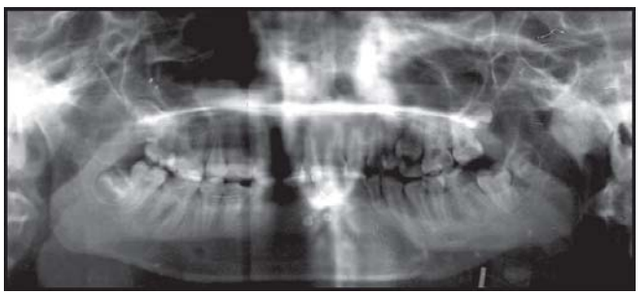

Fig. 18.11B: Ankylosis, OPG shows a well defined radiopaque area in relation to the left condyle

Fig. 18.11C: 3DCT showing ankylosis (Ref. Fig. 18.11B)

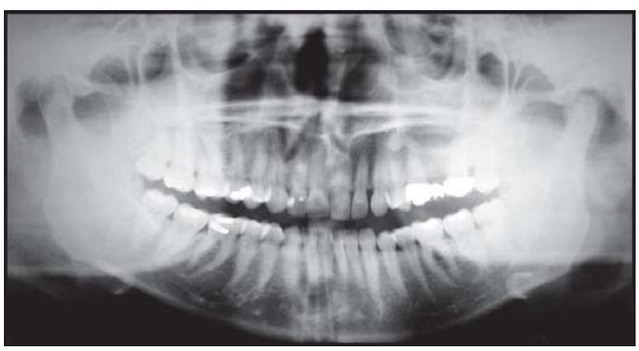

Fig. 18.11D: OPG showing flattening of the condyles and osteophytes- Rheumatoid arthritis

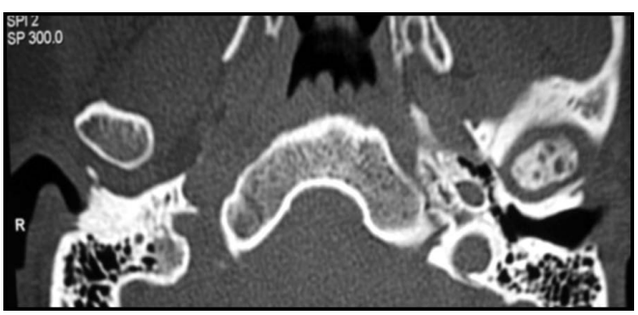

Fig. 18.11E: CT showing arthritic changes-sclerosis of the outer-surface of the condyle - Rheumatoid artheritis (Ref. Fig. 18.11D)

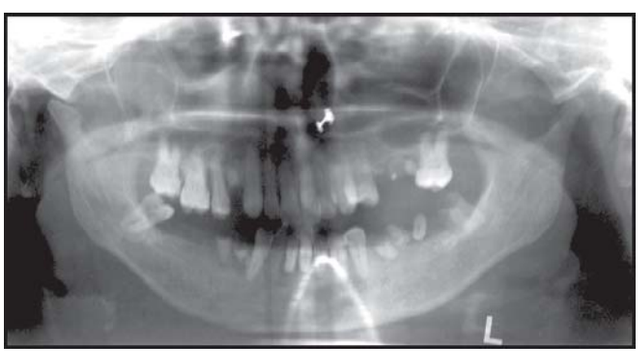

Fig. 18.11F: Flat condyle

Fig. 18.11G: Pencil shaped condyle

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	juvenile rheumatoid arthritis	– Flattening of the articular eminence and erosion of the superior portion of the condyle. – In severe cases ankylosis may occur.
	Infectious arthritis	– Increase in the joint space.
>	trauma	
	fracture	– Unilateral fracture are more common. – Displacement is seen on the radiographs an anterior and medial deviation of the condylar fragment
	Ankylosis	– ro mass, ie. New bone, obliterating the joint space. – Narrowing of the TMJ space, loss of condylar head and fossa morphology. – Non translation of the condylar head on opening.
>	developmental defects	
	condylar hypoplasia	– Small defective condylar head, missing condyle head.
	condylar hyperplasia	– Hyperplastic deformity of the condylar head, displacement from the fossa, mandibular deviation to the normal side.
>	neoplasia	
	benign tumors	– Hypertrophy and deformity of the condylar head.
	Osteoma	– Deviation of the jaw to the normal side.
	Osteochondroma	
	chondroma	
	chondroblastoma	
	fibromyxoma	
	benign giant cell lesion	
	synovial chondromatosis	
	malignant tumors	– Degeneration of the conylar head.
	chondrosarcoma	very rare

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	synovial sarcoma fibrosarcoma multiple myeloma	
	TMJ dislocation (luxation)	
	Anterior	– Anterio superior displacement of the condylar head beyond the articular eminence
	Lateral	– Flattened articular eminence (habitual).
	Habitual	– Enlarged TMJ space. – Unilateral TMJ luxation resulting of deviation of the mandible to the normal side.
12.	Para Nasal Sinuses (Fig. 18.12)	
	> inflammatory changes thickened mucosa	– ro band, which is more ro than the air filled sinus. – Even opacification of the involved antrum
	Sinusitis	– Image of the thickened mucosa will tend to be parallel to the wall.
	Acute	– In case of an allergic reaction, the mucosa tends to be more lobulated.
	Chronic	– No bony destruction of the surrounding bone seen.
	Fluid levels (2 radiographs- one in upright position and the other is lying down position.)	– Translucency of a portion of the sinus is reduced with a line of demarcation between the translucent and more opaque portion. On changing position a new level is formed.
	Empyema	– Decalcification of the surrounding bone wall, and haziness of the trabeculae next to the sinus wall.
	Polyps	– Opacification, with bone destruction or displacement.
	mucosal retention cysts	– Uniform cloudiness – Semicircular or dome shaped appearance near the floor of the sinus with a faint radiopacity. – Well defined margins. – No peripheral bony destruction

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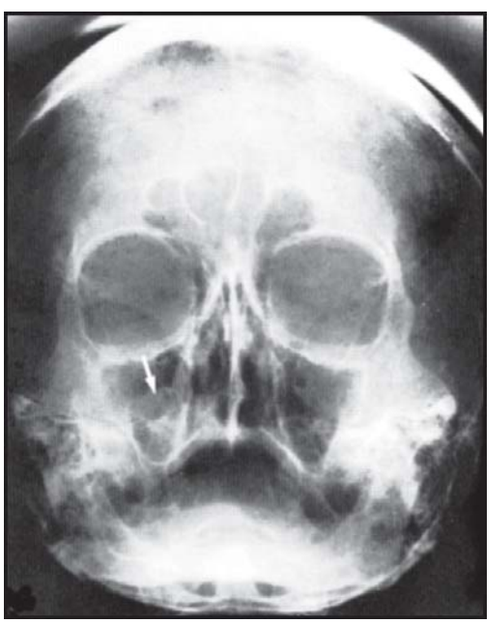

Fig. 18.12: Water's view showing dome shaped radiopacity in the right maxillary sinus- mucus retention phenomenon

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	mucocoele	– Opacification of the sinus. – Loss of normal mucoperiosteal line and bony expansion. – Erosion of the septa and bony walls may occur.
	Carcinoma	– Opacification – Descending type shows destruction of the floor of the sinus. – Advanced cases involve destruction of TM line and zygomatic arch.
	Odontogenic Maxillary Sinusitis	– Opacification with root fragment in the sinus, or break in the floor due to perforation. – Infected maxillary first molar
	Post operative maxillary	– Pneumatization.
	Cyst(Sialography of the antrum)	– Well defined unilocular rl, with margins showing osteosclerotic changes. – Resorption of the maxillary alveolar process.
	Foreign objects within Maxillary sinus	– Abnormal radiopacities surrounded sometimes by increased rl.
13.	Soft Tissue calcification (Figs 18.13A to D)	
	Lymph Nodes	– Multiple, irregular, calcific masses of variable sizes. – May have a laminated appearance. – Image may be projected over the posterior body and angle of the mandible.
	Sialolith	– Circular oval radiopacities with faint margins and even radiodensity.

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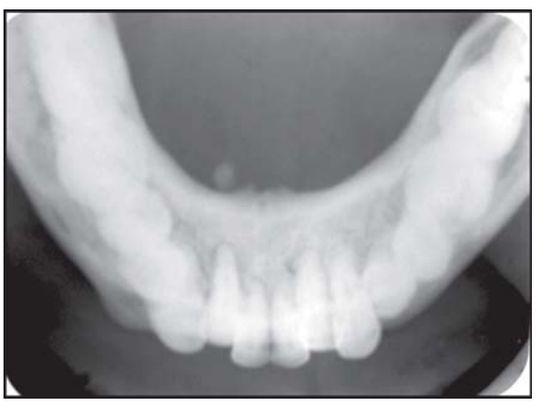

Fig. 18.13A: Mandibular occlusal showing sialolithiasis

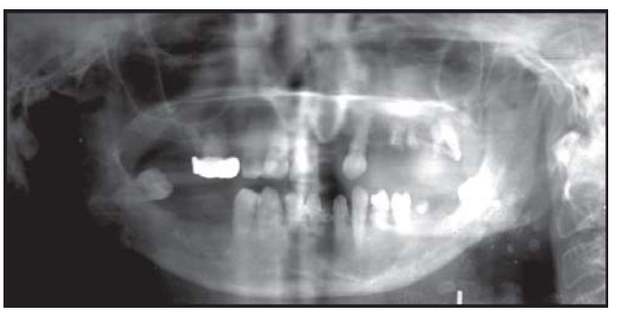

Fig. 18.13B: Calcified phleboliths in hemangioma

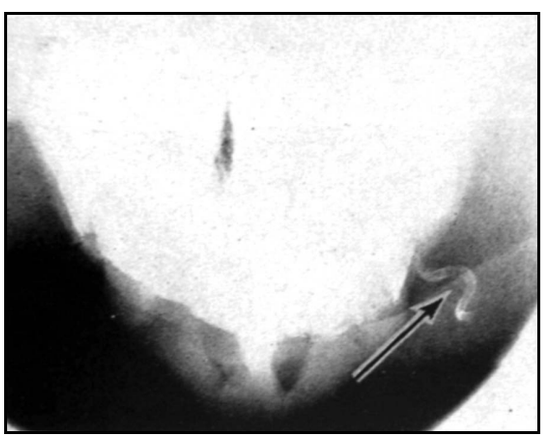

Fig. 18.13C: Facial artery calcification

Fig. 18.13D: Myositis ossificans involving masseter muscle

Contd...

S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	(occlucal, AP-open mouth Lateral oblique)	– When present in the duct they have a cylindrical shape.
	Antroliths	– Attached to the wall of the sinus. – rl-ro, laminated appearance, with variable size and out line.
	Calcified Ligament (Eagle's syndrome)	– Prominent long, tapering ro process located between the mastoid process and the ramus. – It is thicker at the base and projects downwards and forwards. – It varies from 0.5 to 2.5 cms in length. And may appear to extend to the lesser horn of the hyoid bone.
	Pheboliths	– Small round or oval homogenous multiple ro. – Usually occur in relation to haemangioma.
14.	Trauma to teeth and facial structures (Figs 18.14A to E)	
	Teeth	
	Concussion	– Widening of the periodontal ligament space.
	Luxation	– Widening of the periodontal ligament space. – Extruded teeth. – Intrusion leads to indistinct lamina dura.
	Avulsion	– Empty socket.
	Fracture of teeth	– Fracture line observed depending on the angulation used.
	zygomatic arch (jug handle view)	– Mid fracture of the arch (V-shaped medial displacement)
	alveolar process	– Usually combined with the fracture of the teeth, fracture line may not be apparent on the radiograph.
	Maxilla	
	Le Fort I (Horizontal)	– Fracture line.
	Le Fort II (pyramidal)	– Abnormal occlusion
	Le Fort III (Craniofacial dysjunction)	– Clouding of maxillary sinus, caused due to bleeding.
	mandible (occlusal, lateral oblique)	– Fracture line
	midline	– Body of the mandible displacement
	Mandibular angle	– Dislocation of the fragment
	Body of the mandible	– Step deformity
	Canine area	

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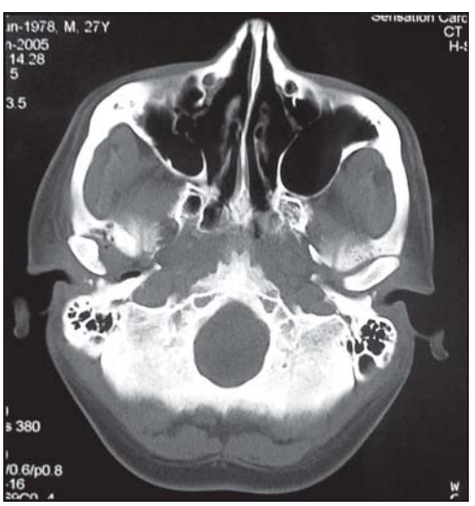

Fig. 18.14A: Axial CT showing fracture of the greater wing of right sphenoid, with diplacement

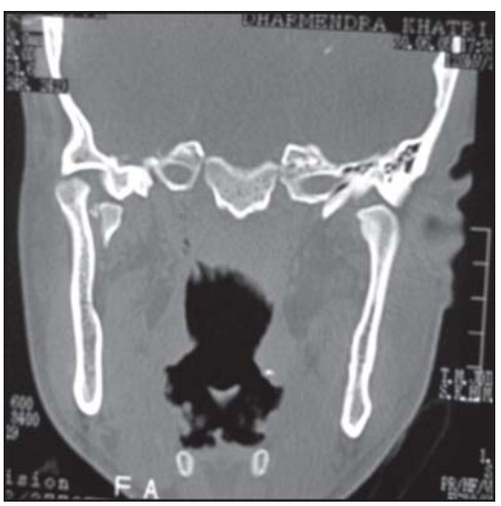

Fig. 18.14B: Coronal CT showing fracture of condyle and inferior displacement (Ref. Fig. 18.14A)

Fig. 18.14C: Root fracture

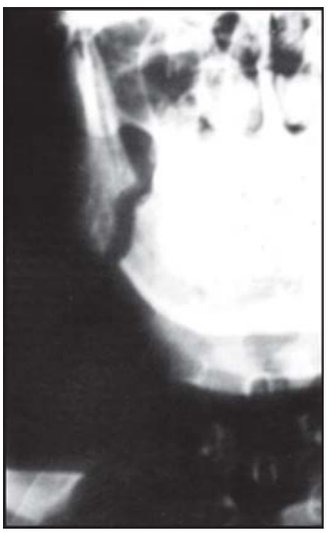

Fig. 18.14D: PA Mandible showing fracture through the angle of mandible with lateral displacement

Fig. 18.14E: Coronal CT showing multiple fractures- lateral wall of the orbit and posterolateral wall of maxillary sinus

Contd...

S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	Mental foramen area	
	Molar area	
	Ramus	
	Condyle neck	
	Coronoid	
15.	Developmental Disturbances of the Face and Jaws.	(Figs 18.15A to C)
	Cleidocranial dysplasia	– Prolonged retention of deciduous teeth with subsequent delay in eruption of succedaneous teeth. – Sometimes associated with cyst formation – Supernumerary impactions, especially in the mandible.

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
		– Over growth of cranial base antero-posteriorly.
		– Flattened mandibular angle.
		– Under developed maxilla.
		– Delayed closing of skull fontenalles.
		– Large number of wormian bones
		– Frontal and occipital bossing
		– Basilar invagination
		– Missing or underdevelopment of bilateral or unilateral clavicle.
	Craniofacial dysostosis (Crouzon's disease)	– Digital markings in the skull as a result of increased intra cranial pressure from early synostosis of cranial sutures.
		– Malformation of calvarium.
		– Flattened mandibular angle.
		– Mandibular prognathism
		– High arched palate
		– Partial anodontia and conical teeth.
		– Hypertelorism, optic neuritis and blindness.
	Mandibulofacial dysostosis (Treacher Collins Syndrome)	– Hypoplasia of facial bones, mandible and maxillary sinus.
		– Partial anodontia.
		– Malformation of teeth.
		– Prolonged retention of deciduous teeth with subsequent delayed eruption of succedaneous teeth; malalignment, macrostomia
		– External ear malformation, facial clefts, high arched palate
		– Fish like appearance of face
		– Under developed zygomatic bones and mandible
		– Steep mandibular angle
		– Downward inclination of palpebral fissures
	Hemifacial hypertrophy	– Enlargement of bone on the affected side.
	Hemifacial hypoplasia	– Reduction in the size of bone on the affected side.
	Hypoplasia of maxillary tuberosity	– Bilaterally enlarged tuberosities which are more opaque than normal.
	Developmental salivary gland defect	– Round or ovoid rl, surrounded by a well defined ro line, usually found below the mandibular canal and above the inferior border of the mandible, anterior to the angle of the mandible and behind the third molar.
	Cleft palate	– Alveolar bone in the region of the cleft reveal numerous dental deformities, absence of maxillary lateral incisor, presence of supernumerary teeth, other teeth may be malformed and malpositioned.
	Ectodermal dysplasia	– Hypoplasia of the alveolar process.
		– Cone shaped teeth.
		– Prolonged retention of primary teeth with subsequent retention of succedaneous teeth.
		– First premolars are often missing.
		– Partial or total anodontia.
		– Abnormalities of hair, skin or nails.
	Papillon-Lefevre Syndrome (Hyperkeratosis Palmoplantaris)	– Advanced periodontitis of primary and permanent dentition.
		– Prominent destruction and resorption of the alveolar bone.
		– Hyperkeratosis of the palms of the hands and soles.
	Pyknodysostosis	– Osterscleroticchanges of the bone.
		– Underdeveloped bimaxilla.
		– Hypercementosis.
		– Flattened mandibular angle.
		– Bones are prone to pathological fracture.
		– Skull sutures remain open.
		– Hypoplasia of the digital bones

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
	Chromosomal Disorder (Downs Syndrome)	– Hypoplastic maxilla, high arched palate – Microdontia with shortened roots. – Malalignment. – Cleft palate. – Round and exophytic mandibular angle. – Mongolism, sexual underdevelopment – Increased incidence of leukemia – Open fontanelles – Dental retardation – Macroglossia
	Basal Cell Nevus Syndrome (Gorlin-Goltz Syndrome)	– Multiple jaw cysts (usually unilocular odontogenic keratocysts in the mandible). – Multiple nevoid basal cell carcinoma, with occasional – Malignant transformation.

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Fig. 18.15A: Heriditary ectodermal dysplasia

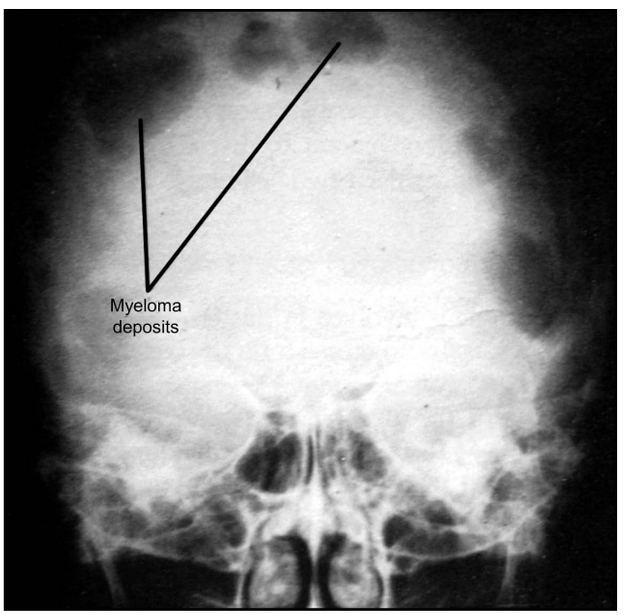

Fig. 18.15B: Punched out lesions of multiple myeloma

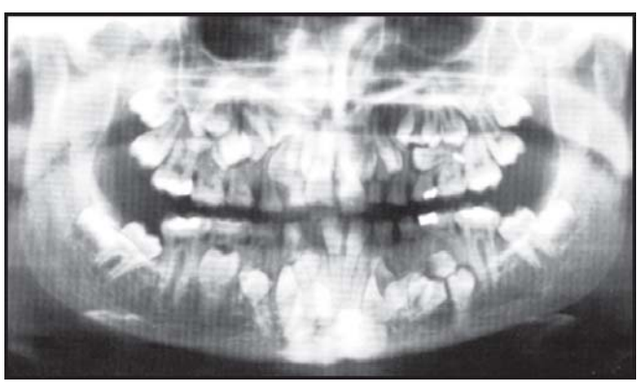

Fig. 18.15C: OPG showing retention of multiple primary teeth and multiple unerupted supernumerary teeth

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S.No.	*Pathology (Radiographic view recommended)*	*Radiographic appearance*
		– Bifid ribs.
		– Calcification of falx cerebi
		– (Basal cell carcinoma)
	Familial Intestinal	– Osteomas in the jaws.
	Polyposis	– Osteoid odontogenic-like radiopacities in the mandible
	Gardner's Syndrome	– Multiple unerupted supernumerary and permenant teeth in both jaws.
		– (Intestinal polyposis.)
		– (Multiple epidermoid or sebaceous cysts of the skin.)
		– (Subcutaneous fibromas)
	Peutz Jeghers Syndrome	– Osteomas in the jaw bones.
		– (Intestinal polyposis.)
		– Melanin pigment of the lips and oral mucosa, appearing as small round macules.
	Van Buchem's Disease	– Skeleton shows thickening and increase in density.
		– Ribs are involved.
		– Marked thickening of the skull
		– Mandible shows thickening of the cortex, especially in the anterior region.
		– The angle of the mandible is rounded.
	Pyle's Disease	– change in the bone pattern of the maxilla and the mandible, similar to that in Fibrous dysplasia.
	(metaphyseal dysplasia)	– Maxilla enlarges vertically.
		– Angle of the mandible is more obtuse.
		– Teeth are separated.
		– Skull is thickened, esp. in the base and frontal bone.
		– Air sinuses are small or absent.
		– Long bones are enlarged at the distal ends, like 'Indian clubs'
	Engelmann's Disease	– Leontiasis ossea may be present
	(diaphyseal dysplasia)	– Bone pattern is amorphorous
		– Mandible and maxilla show increase in depth and density
		– Angle of the mandible is rounded
		– Teeth may have delayed eruption
		– Skull shows thickening and increased density of the frontal and parietal bones
		– Symmetrical enlargement of the shafts of the long bones.
	Marfan Syndrome	– Dolicocephaly
	(Abraham Lincon had this	– High arched palate
	syndrome)	– Mandibular proganthism
		– Brachnodactyly (spider like fingers)
		– Long thin extremities
	Eagle's Syndrome	– Elongated styloid process or an ossified styloid ligament
		– Severe unilateral pain
	Costen's syndrome	– (Clicking of TMJ)
		– Over closure of the mandible
		– Impaired hearing and tinnitus
	Crest Syndrome	– Calcinosis cutis
		– Raynaud's phenomenon
		– Esophageal dysfunction
	Pierre-Robin Syndrome	– Cleft palate
		– Micrognathia
		– Glossoptosis
	Syphillis (Hutchson's Triad)	– Hypoplasia of incisor and molar teeth
		– Peg shaped lateral
		– Mulberry molar
		– (8th nerve deafness and interstitial keratosis)

*rl-radiolucent, ro-radiopaque, pdl-peridontal ligament

Table 18.2: Causes of external resorption of tooth

Physiological	*Pathological*
Deciduous Dentition	Reimplanted teeth nonvital teeth unerrupted teeth retained roots impacted teeth orthodontic treatment traumatic occlusion foreign body tooth fracture cyst giant cell lesion hyperparathyroidism idiopathic

Table 18.3: Commonly occurring radiolucent lesions

Unilocular	*Multilocular or Psuedolocular*	*Lesions which may develop internal radiopaque calcifications*
• Radicular cysts • Dentigerous cyst • Nasopalatine duct cyst • Median mandibular cyst • Solitary bone cyst • Secondary (metastatic) tumour • Calcifying epithelial odontogenic cyst • Adenomatoid odontogenic-tumour • Multiple myeloma • Eosinophillic granuloma • Fibro-osseous lesions • Stafne's bone cavity	Odontogenic keratocyst Ameloblastoma Ameloblastic fibroma Odontogenic fibroma Odontogenic myxoma giant cell lesions granuloma brown tumour cherubism Aneurysmal bone cyst	• Calcifying epithelial odontogenic tumour • Adenomatoid odontogenic tumour • Calcifying odontogenic cyst • Chondroma • Fibro-osseous lesions • Osteogenic sarcoma • Cancellous Osteoma • Fibrous dysplasia • Ossifying fibroma • Cementifying fibroma • Gigantiform cementoma • Periapical cemental dysplasia • true cementoma (cemetoblastoma)

Table 18.4: Commonly occurring radiopaque lesions

A. Abnormalities of teeth
- Unerupted and misplaced teeth including supernumeraries.
- Odontomes
  - compound
  - complex
- Root remnants
- Hypercementosis

B. Conditions of variable radiopacity effecting the bone
- Developmental
  - exostoses including tori-mandibular or palatal.
- Inflammatory
  - low grade infections
  - sclerosing osteitis
  - osteomyelitis- sequestra and involucrum formation.
- Tumors
  - Odontogenic (late stages)
    - ➢ calcifying epithelial odontogenic tumor (CEOT)
    - ➢ adenomatoid odontogenic tumor
    - ➢ calcifying odontogenic cyst
  - Non-odontogenic
    - ➢ Benign
      - # osteoma
      - # chondroma
    - ➢ Malignant
      - # osteosarcoma
      - # osteogenic secondary metastases
- Fibro-osseous lesions (late stages)
  - fibrous dysplasia
  - ossifying fibroma
  - cementifying fibroma
  - true cementoma (cementoblastoma)
  - periapical cemental dysplasia
  - gigantiform cementoma
- Others
  - Paget's disease
  - Osteopetrosis

C. Superimposed soft tissue calcifications
- Salivary calculi
- Calcified lymph nodes
- Calcified tonsils
- Phleboliths
- Calcified acne scars

D. Foreign bodies
- Intra-bony
- Within the soft tissues on or overlying the skin

BIBLIOGRAPHY

1. Avinash Kshar, Ani John, Hemant Umarji, Adenomatoid Odontogenic Tumor-Report of three cases. JIAOMR Vol. 17, No. 2, Pg 61, April-June 2005.
2. Coaz PW White SC Principles of Image Interpretation: In Oral Radiology. Principles of Interpretation, 3rd ed. St Louis, Mosby-Year Book, 1994.
3. Miles DA, Van Dis ML, Jensen CW, Ferretti A. Interpretation. Normal versus abnormal and common radiographic presentation of lesions. In Radiographic Imaging for Dental Auxiliaries, 3rd ed. Philadelphia, WB Saunders, 1999; 231-80.
4. Worth HM. Principles and Practice of Oral Radiologic Interpretation, Chicago, 1972, Mosby.

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